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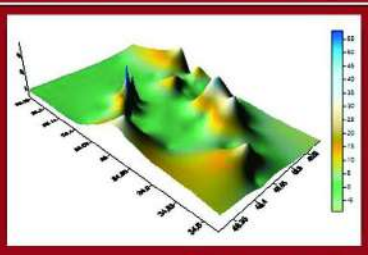

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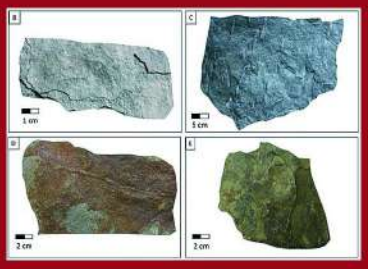

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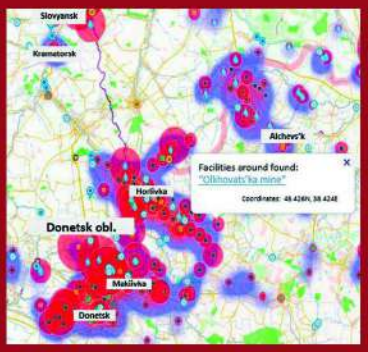

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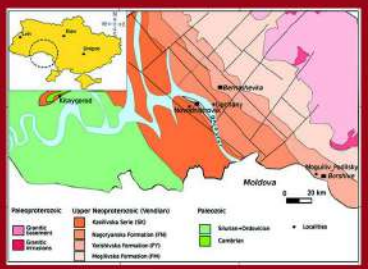

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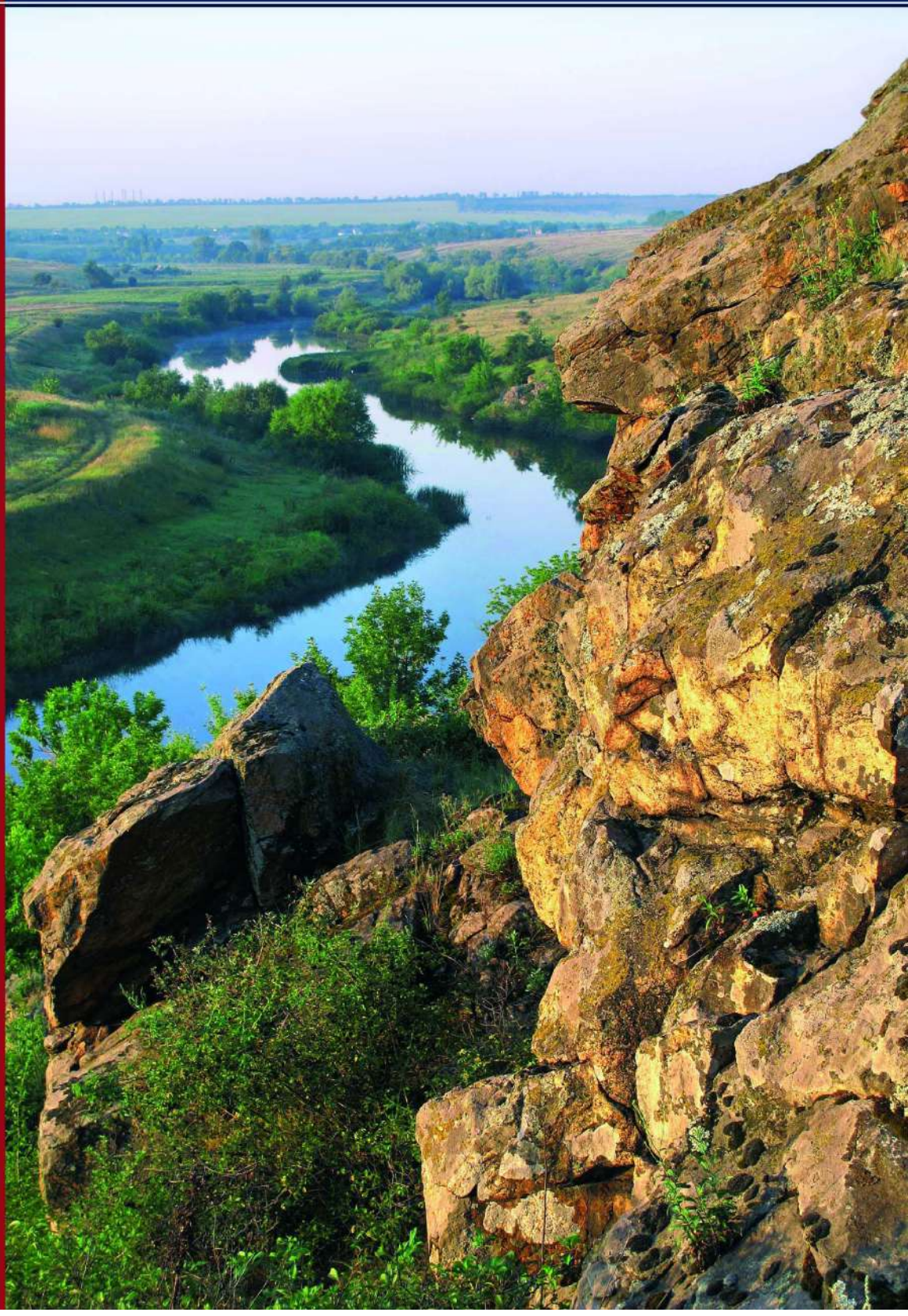

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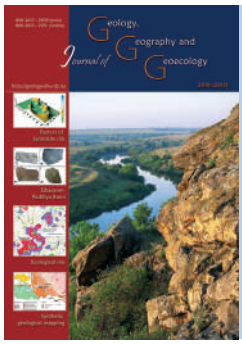

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Effect of Land Use/Land Cover Change on Groundwater Recharge in Osun Drainage Basin, Nigeria

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Abstract. Abstract. Osun drainage basin is one of the regions in Nigeria experiencing increasing population growth and rapid urbanization; and about 70% of the inhabitants rely on shallow groundwater resources of the region. Change in land use/land cover is one of the significant factors controlling regional hydrology and groundwater resources, thus the continuous change in land use and land cover of the drainage basin will significantly affect the basin's groundwater resources. There are 7 classified land use/land cover in the study area which are bare surfaces, built up area, crops/shrubs, forest, rock outcrops, water bodies and wetland. Applying WetSpass-M hydrological model, we predicted the effect of land use/land cover change on the groundwater recharge in Osun drainage basin, Nigeria between 1984-2015. The results revealed that the highest groundwater recharge of 48.56%, 33.64% and 37.29% occurred in forested area in 1984, 2000 and 2015, respectively. This result might be due to the influence of vegetation in slowing down the speed of running water across the forest area, that allows more infiltration and deep percolation into the water table to recharge the groundwater system. On the other hand, the least groundwater recharge of the total annual was on the rock outcrops, which are about 4% in 1984, 3% in 2000 and 2% in 2015. The least recharge found on rock outcrops is expected and may be attributed to the fact that infiltration can only occur around or on decomposed rock outcrop, which may result in minute recharge to the groundwater system. The mean annual groundwater recharge of the basin for the land use/land cover of 1984, 2000 and 2015 are 476.54, 411.07 and 430.06 mm/y, respectively. Overall, for the 32 years period of investigation, change in land use/land cover accounts for only 10% reduction in mean groundwater recharge occurrence between 1984 and 2015. Also, there is a change in recharge pattern in the study area during this period because most often, change in land use/land cover is a transition from one land use/land cover class to another, and the recharge pattern is influenced based on the degree of transition that took place and the characteristics of the dominant land use/land cover at a particular area of the basin. Although, the 10% reduction in mean annual recharge appears minute, this might become pronounced if the current rate of deforestation in the drainage basin continues unabated. Therefore, proper land use allocation, regulated land development and afforestation in terms of planting of native trees that were lost through anthropogenic activities in the basin should be policy option for groundwater sustainability.

Keywords: Land use and land cover, Groundwater, recharge, WetSpass, Osun drainage basin

Вплив землекористування (зміни земного покриву) на поповнення запасів підземних вод в басейні річки Осун, Нігерія

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Анотація. Перші зВодосховище Осуна є одним з регіонів Нігерії, де спостерігається зростання населення і швидка урбанізація; і близько 70% жителів покладаються на неглибокі ресурси ґрунтових вод регіону. Зміна умов землекористування є одним з важливих факторів, що контролюють регіональну гідрологію та ресурси підземних вод. Таким чином, безперервна зміна використання землі та земельного покриву водозбірного басейну суттєво впливає на ресурси ґрунтових вод басейну. У досліджуваному районі є 7 класифікованих земельних ділянок (землекористування), якими є відкриті поверхні, забудовані території, сільськогосподарські угіддя, чагарники, ліси, відслонення гірських порід, водоймища та водно-болотні угіддя. Застосовуючи гідрологічну модель WetSpass-M, ми прогнозували вплив зміни землекористування на живлення підземних вод

в басейні водосховища Осун (Нігерія) в період з 1984 по 2015 рік. Результати показали, що найбільша поповнення підземних вод 48,56%, 33,64% та 37,29% відбулося у лісовій зоні у 1984, 2000 та 2015 роках відповідно. Цей результат може бути зумовлений впливом рослинності на уповільнення швидкості просочування води через лісову підстилку. З іншого боку, найменше поповнення підземних вод у загальному обсязі річного видобутку відбувалося на виходах гірських порід, які становили близько 4% у 1984 році, 3% у 2000 році та 2% у 2015 році. Очікується найменше поповнення, виявлене на відкритих скелях, і може бути пов'язане з тим, що інфільтрація може відбуватися тільки навколо або на звітрених, дезінтегрованих ділянках порід, що може призвести до короткочасного поповнення системи підземних вод. Середньорічне поповнення підземних вод у басейні для землекористування (земного покриву) у 1984, 2000 та 2015 років становить 476,54, 411,07 та 430,06 мм / год відповідно. В цілому, протягом 32-річного періоду досліджень, зміна землекористування (земного покриву) дає лише 10% скорочення середнього рівня живлення підземних вод у період з 1984 по 2015 рік. Найчастіше, зміна землекористування - це перехід від одного класу землекористування до іншого, і схема поповнення залежать від ступеня переходу, що мав місце, і характеристик домінуючого землекористування на певній території басейну. Хоча, 10% скорочення середнього щорічного живлення з'являється хвилини, це може стати яскраво вираженим, якщо нинішня швидкість вирубки лісів у водозбірному басейні продовжується. Таким чином, належне ведення землекористування, регульоване освоєння земель та лісорозведення з посадкою районованих дерев, які були втрачені внаслідок антропогенної діяльності в басейні, має бути політичним рішенням проблеми забезпечення стійкості підземних вод.

Ключові слова: землекористування та земний покрив, підземні води, живлення, WetSpass, Осунський дренажний басейн

Introduction. Change in land use/land cover (LULC) is an important factor influencing the groundwater system. Since the beginning of industrialization, intensive anthropogenic activities that include agriculture, urbanization mining, etc. have consequently resulted to alteration of the physical landscape with effect on the regional water balance of surface and groundwater systems (Bronstert, 2004; Albhaisi, et al., 2013). Land use type and the native land cover of any particular area influence water as it moves through a drainage, which can change downstream delivery via ecosystem interactions such as rainfall interception, evapotranspiration rate, macropore development, and environmental filtration (Brauman et al., 2007). The connection between land use and water resources is of significant importance to groundwater governance and management, mainly because change in land use can have a life time effects on groundwater and some land use change events can have an unredeemable influence on aquifers and groundwater storage (Foster and Cherlet, 2014). As a matter of fact, the rate at which the natural landscape is changing as a result of population increase, urbanization, various anthropogenic activities and the large-scale conversion of land from a particular use to another is alarming all over the world.

Sala et al. (2000) and Vorosmarty et al., (2000) had earlier reported that the impacts of land-use change on the world water resources and ecosystem biodiversity may surpassed that of climate change in the 21st century. The implications of land use change that include: changes in land use practices and its associated changes in water demand, irrigation projects and urbanization; changes in water supply from modified hydrological processes of infiltration, groundwater recharge and runoff; and changes in water quality from agricultural runoff and suburban development should be fully understood (DeFries and Eshleman, 2004) and of necessity integrated into the emerging land use change science of the future (Turner et al., 2003; DeFries and Eshleman, 2004). However, despite the evidences that abound that every decision made on land use practice has an impression on water resources, it is yet to be largely incorporated into integrated management practices by policy makers (IFAD, 2010 cited in Foster and Cherlet, 2014). Therefore, in order to protect and enhance water resources generally, and groundwater in particular, managers need to know and understand how land-use decisions and allocation will impact on the flow of water (Brauman et al., 2012).

In recent years, some studies have tried to evaluate the effect of LULC change on groundwater resources around the world. For example, Zamlot et al., (2015) predicted the effect of LULC on groundwater recharge in Flinders, Belgium and they discovered that forest land-use type has a positive higher effect on groundwater recharge. Albhaisi et al. (2013) also examined the effect of LULC change on groundwater recharge in upper Berg catchment, South Africa. They discovered that groundwater recharge on bare LULC class increases significantly from 23% in 1984 to 64.7% in 2008. The influence of LULC change on groundwater recharge was investigated by Dams et al. (2008) in Kleine Nete Catchment, Belgium. They adopted four LULC change between 2000 and 2020. They observed that recharge reduced in urban centres in all the land use change scenarios. Pan et al. (2011) investigated the hydrological processes and recharge ability of various land use types in Guishui River Basin, China. They discovered that the annual-lumped groundwater recharge rate decreases in the order of cropland, grassland, urban land, and forest, which has resulted in a decrease of 4×106 m^3/year of groundwater recharge between 1980 and 2005. They attributed the decrease in groundwater recharge

observed to an increase in urban area and rural settlements; and decrease in cropland land use class.

Most of the studies on the effect of land-use change on groundwater research has principally focused on the change in water quality thereby neglecting changes in quantity (Dam et al., 2008), and this is the scenario in the Nigeria context. The scarcity of the studies on effect of land use on groundwater quantity in Nigeria are closely related to the views of De Fries and Eshleman (2004), that evaluating the effect of land use change on groundwater quantity is complicated by the comparatively short lengths of hydrological records; the comparatively high natural variability of most hydrological systems; and the difficulties in controlling land-use changes in real catchments within which changes are taking place. In addition, the complex nature of groundwater hydrology, the complexities of its interaction with the ecosystem, and the inadequate record on hydrological processes made such study scarce in Nigeria. Meantime the recent advancement in Satellite remote sensing data collection and the improvement in modelling of hydrological processes have made the study more feasible. However, embracing the advancement in these technologies to quantify the effect of changing land use on groundwater quantity is still evolving in Nigeria. Therefore, this present study attempts to predict the effect of land use and land cover change on groundwater recharge in Osun drainage basin (Nigeria) using satellite remote sensing data and WetSpass-M hydrological model.

Osun drainage basin is one of the two major drainage basins in the southwestern Nigeria, and it cut across about six states. About seventy-five percent of the inhabitants of the basin depend on groundwater as a source of water for their domestic consumption. Osun drainage basin is an area naturally characterized by rainforest vegetation. The natural vegetation, has however, been replaced by secondary forest due to many years of anthropogenic activities through vegetation clearing and increasing urbanization (Ifabiyi, 2005). The basin has witnessed one of the fastest rates of forest conversion and change in vegetation in Nigeria. This is as a consequence of fuel wood production, road construction, clay/sand quarrying, widespread rotational bush farming, as well as high rate of emerging cities. In fact, the population of the area has been increasing and the urban centres located therein are growing rapidly. Studies on LULC in different parts of the drainage basin have suggested rapid changes in LULC all over the basin (Gasu, et al. 2016; Mengistu and Salami, 2007; Akinyemi, 2005; Salami et al., 1999; Salami, 1995), which will impact the water balance of the basin.

All these changes in land use/land cover will have significant feedback on the water balance of the basin. The groundwater resources of the drainage area will be influenced by the prevailing incidences of LULC change. This might stress the existing groundwater supply, with increasing risk of reduced groundwater recharge. Consequently, the ability of the groundwater system to meet the increasing water need now, in the future and sustaining the ecosystem will be at greater risk. This study will assist in understanding the implications of LULC change on groundwater resources in Osun drainage basin and it will inform land use allocation and management within the basin that will discourage unregulated and uncontrolled land use development that may pose great risk to groundwater system in particular and the environment in general. Meanwhile, the manifestation of a declining groundwater resource was observed in the upper part of the Osun drainage basin more than three decades ago (Omorinbola, 1982). The decline, attributed to the level of urbanization, number of well per unit area and the clearing of rainforest for commercial scale agriculture, as of that time has witnessed tremendous urbanization with emerging cities such as Osogbo, Ede, Ilesha, Ikirun, Iwo, Ogbomosho, Oke Imesi, etc. expanding in leaps and bounds. With population increase, no doubt, more vegetation has been cleared to give way for urbanization, hence, predicting the effect of such change on LULC will enhance sustainable groundwater management in the drainage basin.

Study Area. The study area is located between latitudes 6°25′58.79″ and 8°21′3.6″ N and longitudes 3°47′34.8″ and 5°10′55.2″ E in the southwestern Nigeria (Figure 1). River Osun which is the major river in the drainage system accents in Oke-Mesi ridge, about 5 km North of Effon Alaiye and flows North across the Itawure gap to latitude 7°53″ and then deviates westwards via Osogbo, Ede and southwards to flow into Lagos lagoon (Oke, et. al., 2013; Ashaolu, 2016; Ogun-Oshun River Basin Development Authority [OORBDA], 1982). The basin climate is influenced by the movement of the Inter-tropical Convergence Zone (ITCZ), the quazi-stationary boundary that distinguishes the sub-tropical continental air mass over the Sahara and the equatorial maritime air mas over the Atlantic Ocean (OORBDA, 1982). The climate of the basin can be described as the tropical continental climate of Koppen Aw type humid tropical rainforest climate (Ifabiyi, 2005). The basin experiences two types of seasons, dry and rainy (wet) season. The switch from the rainy season to the dry season is abrupt, while the onset of the rain after the dry season is gradual (OORBDA, 1982).

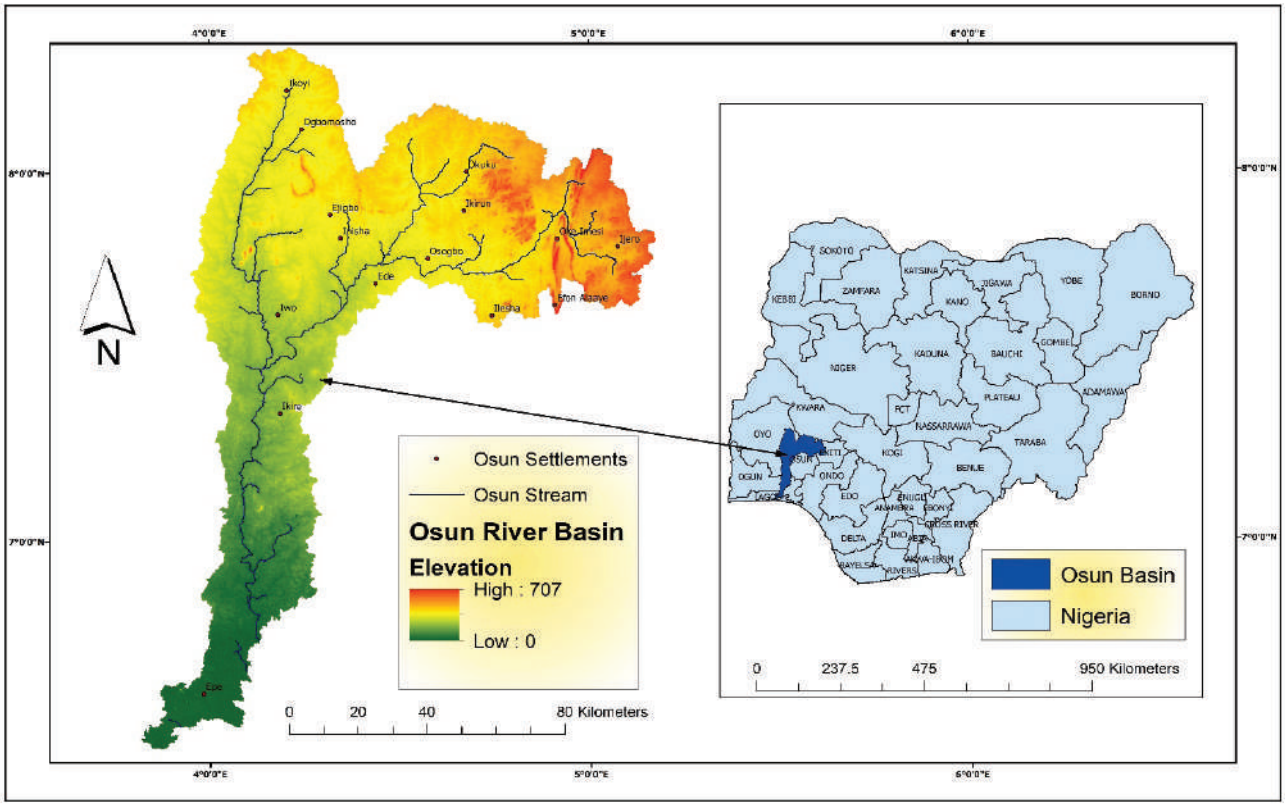

Fig. 1 Location and Position of Osun Drainage Basin, Nigeria. Source: Modified from Ashaolu (2016)

The rainy season begins earlier in the south around March and continues until the end of October or early November. In the north around Ogbomosho, the rain begins in late April or early May and end in mid-October, giving six months of rainfall. The mean wet season rainfall varies from 1,020mm to 1,520mm in the south of the basin and less than 1,020mm in the north. On the other hand, the mean dry season rainfall varies from 127 to 178mm in the north, while it varies from 178 to 254mm in the south (OORBDA, 1982). The months of February and March are the hottest in the basin and temperatures are high over the entire basin during this period. There is also variation in temperature from the south to the north, where it higher. The lowest mean minimum temperature in the north is usually in December during Harmattans, while it is usually recorded in July during the rainy season in the southern part of the basin (OORBDA, 1982). The mean annual temperature is about 30°C, which can varies depending on the location and time of the year (Ifabiyi, 2005). In general, relative humidity decreases northwards in the basin. The mean annual humidity varies from 75% in the south to 55% in the north (OORBDA, 1982).

The basin is underlain by two types of rocks which are the Basement Complex rocks and the sedimentary basins (Oke et al., 2013; OORBDA, 1982). About 93% of the basin is underlain by the Basement Complex rocks, while the remaining 7% is sedimentary rock found in the southern part of the basin close to the Atlantic (Ashaolu, 2016). The rock types are the intracrustal group (e.g. granite, gneisses, migmatite etc) and supracrustal (volcanic and sediments), while the lower part of the basin is covered by recent deposits that subdivide into the lithoral and lagoonal sediments of the coastal belts and the alluvial sediments of the major rivers (OORBDA, 1982). The soils belong to the highly ferruginous tropical red soils associated with Basement Complex rocks. As a result of the dense humid forest cover in the area, the soils are generally deep and of two types, namely, deep clayey soils formed on low smooth hill crests and upper slopes; and the more-sandy hill wash soils on the lower slopes (Ifabiyi, 2005). The relief of the basin is generally undulating and descends from an altitude of about 700 meters in Oke lmesi area to 50 meters and below in areas around Epe and Ibeju Lekki in the southern parts of the basin (Ashaolu, 2016).

The land use pattern within the drainage basin includes land use for residential/settlements and built up areas, bare rocks, bare surfaces, crops/shrubs, vegetation/forest and water bodies. Originally, almost all parts of the basin had a natural lowland tropical rain forest vegetation; but this has however, been replaced by secondary forest regrowth as a result of years of human occupation (Ifabiyi, 2005). The population distribution pattern of the basin is quite uneven. The urban population in the basin is larger than the rural population. Besides, available records from different

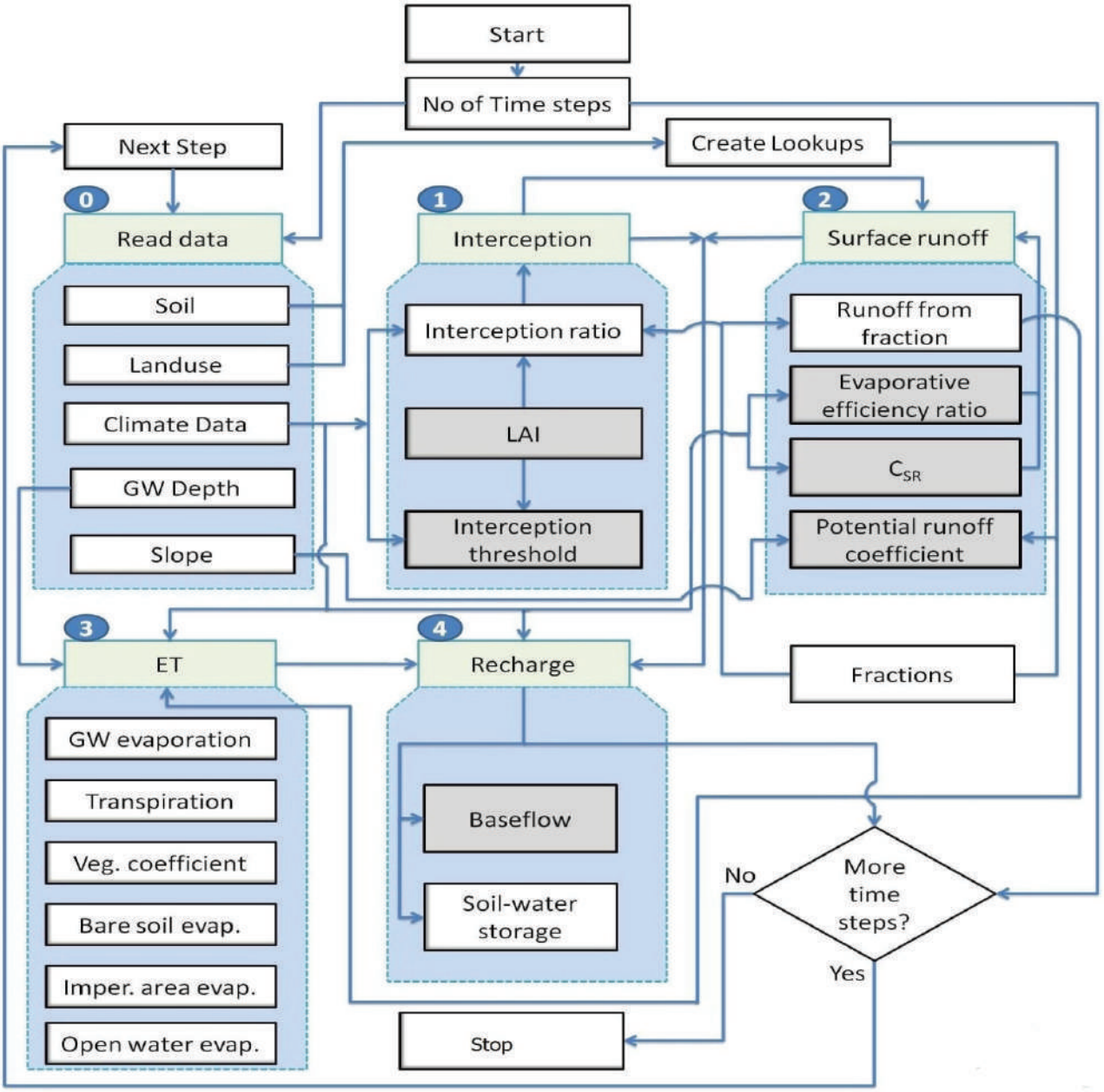

Fig. 2: Flowchart for Monthly Spatially Distributed Water Balance model, WetSpass-M
Source: Abdollahi et al., (2017)

investigations and surveys confirmed the constant movement of population from the rural areas to the cities. Based on the 1963 population census of western Nigeria, the estimated population of the basin made by Ogun-Oshun River Basin Development Authority in 1980 was 4,281,000 and this was estimated to be 12,046,145 in 2015 (Ashaolu, 2018).

Materials and Methods. WetSpaa-M hydrological model was used to estimate mean monthly groundwater recharge in the study area. Block scheme of the flowchart of WetSpass-M water balance model is presented in the figure 2. This model requires two types of input data. There are GIS grid maps and parameters tables (Batelaan and De Smedt, 2001). These grid maps include Digital Elevation Model (DEM), slope, land use/land cover, soil texture, depth to water and monthly climatic maps of rainfall amount, number of rainy days, temperature, potential evapotranspiration and wind speed (Abdollahi, 2015). All the input maps were provided in ESRI ascii grid format. The details on the formulation and application of the model can be found in Abdollahi et al. (2017). The climatic variables used in this study spanned between 1976 to 2015 and it was collected from the Nigeria Metrological Agency (NIMET). Also, Climate Forecast System Reanalysis (CFSR) data by the National Centers for Environmental Prediction (NCEP) were downloaded from https://globalweather.tamu.edu/ website. In all, the climatic variables from 24 weather stations across the study area were used in the study. Mean monthly values of rainfall amount, temperature, potential evapotranspiration and wind speed

were calculated from the available data in each station. The digital maps of the monthly rainfall amount, temperature, potential evapotranspiration and wind speed were created by spatial interpolation of the values observed from the stations, using the universal kriging interpolation module of ArcGIS. The details of the climate preprocessing and data manipulations for the WetSpass-M model was discussed elsewhere (Ashaolu, 2018). The potential evapotranspiration for the same period was estimated using the FAO Penman-Monteith method (Allen et al., 1998).

The classified LULC maps of the study area for the period 1984, 2000 and 2015 were adopted for this study (Ashaolu, 2019). Seven land use/land cover classes such as bare surfaces, built up area, crops/shrubs, forest, rock outcrops, water bodies and wetland were adopted. These seven classes fall under four main category of land use/land cover (vegetated cover, bares soil, open water and impervious surfaces) recognized by WetSpass-M hydrological model. This was done to avoid land use heterogeneity within the pixel (Batelaan and De Smedt 2001; Ampe et al., 2012) and based on the influence such land use/land cover have on water balance of the area. Soil texture map was extracted from the harmonized world soil database version 1.2 (2012) prepared by the Food and Agriculture Organization of the United Nations (FAO) and others. Digital Elevation Model (DEM) with 30m resolution of the study area was obtained from the Shuttle Radar Topography Mission (STRM) of the National Aeronautics and Space Administration (NASA). The slope map was processed from the DEM using ArcGIS. The mean depth to water in the study area reported in the Federal Ministry of Water Resources (FMWR) 2014 national water resource master plan report was adopted. Hence, 10m depth to water was adopted for the 93.28% of the basin underlain by the Basement Complex rocks and 50m for the remaining 6.67% underlain by the sedimentary basin in the south. Discharge data record was obtained from Ogun-Osun River Basin development Authority, Nigeria.

Land-use, soil and runoff characteristics are specified in four parameters tables required for the WetSpass model (Tesfamichael et al., 2013; Batelaan and De Smedt, 2001). These tables were connected to the maps as attribute tables. The land-use attribute table include parameters related to land-use type; such as rooting depth, leaf area index, vegetation height among many others. The soil parameter table contains soil parameters for each textural soil class as field capacity, wilting point, permeability and others. The runoff attribute tables contain parameters for runoff for all combinations of land-uses, slope, and soil type (Tesfamichael et al., 2013). The parameters in the soil types table are based on the United States Department of Agriculture (USDA) soil classification. Also, the runoff attribute table contains values considered to be universal, that is, a certain combination of slope, land-use, and soil type will produce a certain fraction of runoff independent of location (Tesfamichael et al., 2013). After the input data has been prepared, they were inputted into the model to begin the simulation of the monthly water budget of the Osun drainage basin using the LULC map of the year 2000. The outputs include several spatio-temporal (monthly and spatial distribution) hydrologic outputs such as interception, actual evapotranspiration, runoff and recharge. The model was calibrated manually using the following parameters: soil moisture alfa coefficient (α), LP a calibration parameter (–) which reduces the potential evapotranspiration depending on the soil moisture (default is 0.65), interception parameter (a), and runoff delay factor (x) which were optimized according to the goodness of fit between the simulated runoff and the runoff from observed discharge at Apoje station. The calibration started with the soil moisture alfa coefficient (Abdollahi et al., 2017). The coefficient of determination (R^2) and the Nash-Sutcliffe model efficiency (NSE) were used for validation using the simulated and observed discharge data of 1999 at Apoje gauge station. The Pearson moment correlation coefficient of 0.71 exists between the observed and simulated surface runoff, while the Nash-Sutcliffe coefficient is 0.89. However, the groundwater recharge which is the focus of this study was only reported.

After the calibration, to identify the effect of the LULC on groundwater recharge, all the necessary input parameters were inputted, then the simulation with WetSpass-M model was performed by keeping every other input parameter constant, while the land use/land cover of the three epochs (1984, 2000 and 2015) were used one after the other to run the model. This enabled the identification of the effects of land use/land cover changes over time on the groundwater recharge of the basin. This approach was adopted by Pan et al. (2011) and Albhaisi et al. (2013) to evaluate the effect of LULC change on groundwater recharge in Guishi River basin in China and Berg catchment in South Africa, respectively. The recharge on each LULC classes for the three periods (1984, 2000 and 2015) were isolated and aggregated in ArcGIS 10.4. The percentages of recharge occurring on each LULC were computed from the overall basin recharge for each period and the result compared.

Results and Discussion. The sensitivity of LULC change on groundwater recharge in the basin is presented in Table 1. The LULC with highest groundwater recharge in 1984, 2000 and 2015 was on forest land cover which are 48.56%, 33.64% and 37.29%, respectively. This might be due to the influence of vegetation in slowing down the speed of running water across the forest area, that allows more infiltration and deep percolation into the water table. The result agrees with the study of Zamlot et al. (2015) that discovered that forest land-use type have a positive higher effect on groundwater recharge, in Flanders, Belgium. High recharge in the forested area in the basin can be attributed to the preferential flow mechanism through the unsaturated zone. Preferential flow is often associated with tree roots that have created preferential path ways/macro pores in the unsaturated zone with a relatively high infiltration and percolation capabilities (Obuobie, 2008; Lerner et al., 1999; 1990) that allows rainfall easy passage into the saturated zone to recharge the groundwater system.

Table 1. Effect of each LULC Classes Change on Groundwater Recharge

Land Use/Land Cover Types %		*1984 LULC*	*1984 Groundwater Recharge per LULC*	*2000 LULC*	*2000 Groundwater Recharge per LULC*	*2015 LULC*	*2015 Groundwater Recharge per LULC*
		%	%	%	%	%	
1	Bare Surfaces	20.56	20.69	27.30	24.76	31.10	25.98
2	Built Up Areas	3.20	9.46	4.63	10.29	10.72	10.81
3	Crops/Shrubs	16.58	7.55	41.94	19.28	31.38	19.48
4	Forest	52.62	48.56	20.75	33.64	21.71	37.29
5	Rock Outcrops	4.97	4.49	3.45	3.09	4.23	2.44
6	Water Bodies	0.51	0.00	0.62	0.00	0.62	0.00
7	Wetland	1.55	9.25	1.32	8.93	0.24	4.00

The least groundwater recharge in relation to LULC for the three periods was on the rock outcrops, while no recharge takes place on the water bodies. About 4%, 3% and 2% of the total annual recharge occurred on the rock outcrops in 1984, 2000 and 2015, respectively. This is because recharge can only occur on this type of LULC classes in the interface between the outcrops and the loose cracks found around the flat area of the rock outcrops. The least recharge found on rock outcrops is expected and may be attributed to the fact that infiltration can only occur around or on decomposed rock outcrop, which may result in minute recharge to the groundwater system.

Built-up area increases slightly from 3.20% in 1984 to 4.64% in 2000, which resulted in slight increase in total annual groundwater recharge occurrence in built up area from 9.46% to 10.29%. The significant increase in built-up areas from 4.64% in 2000 to 10.72% in 2015 resulted to the built-up area doubling its size. During this period, the relative contribution of built up area to groundwater recharge only increased meagerly from 10.29% to 10.81%. The groundwater recharge occurrence on built-up area did not increased in relation to its size as observed between 1984 and 2000. This suggests that there are more paved surfaces within the built-up expansion by the year 2015. In other words, the spatial expansion of built up area by 2015 in the basin have more impervious surfaces that prevent water to infiltrate and percolate to recharge the groundwater system in and around the built-up areas like the preceding years. The result differs from that of Dams et al. (2008) that used four LULC change between 2000 and 2020, where they observed a reduced recharge in urban centres. The mean monthly occurrence of groundwater recharge in built up LULC class in 1984, 2000 and 2015 is presented in Fig. 3.

Groundwater recharge occurrence on crops/shrubs LULC classes increased from 7.53% to 19.28% between 1984 and 2000. The 11.25% increase in groundwater recharge occurrence on this LULC type, was a consequence of significant increase in crops/shrubs between the same period. Despite about 10% decrease in crops/shrubs between 2000 and 2015, less than 1% increase in groundwater recharge occurrence was still discovered. Groundwater recharge varies over space in all the LULC classes, with some areas of crops/shrubs LULC having little to zero recharge. Therefore, about 10% area of crops/shrubs converted to another use by 2015 might be those areas with little or no recharge. A similar low increase on crops and shrubs

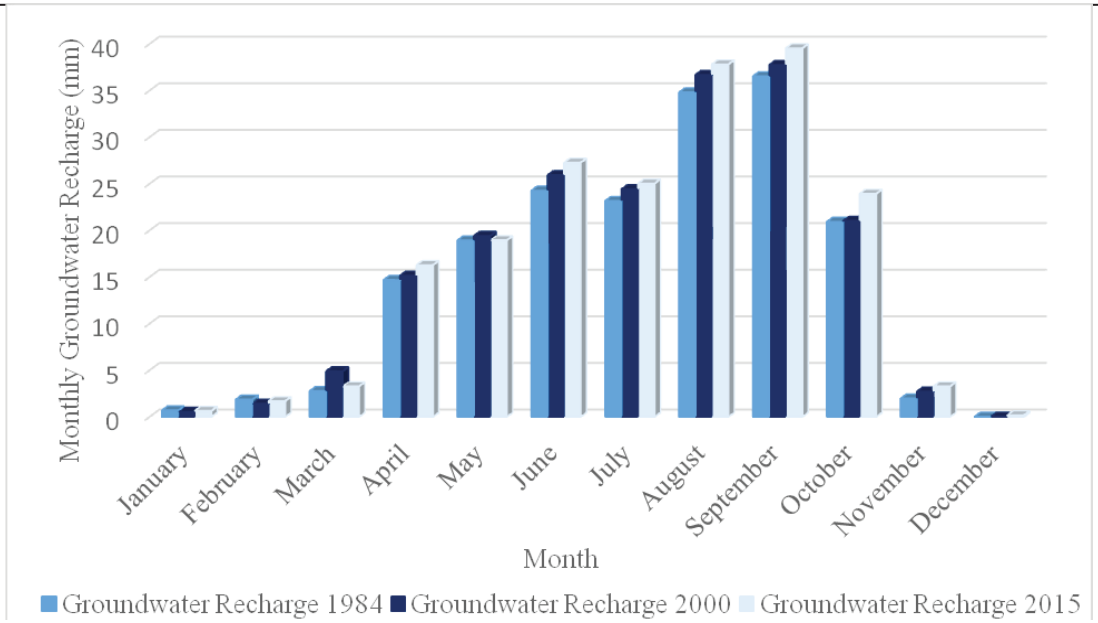

Fig. 3: Mean Monthly Recharge on Built UP Area LULC Class

LULC was observed in upper Berg catchment, South Africa (Albhaisi et al., 2013). The monthly occurrence of groundwater recharge in 1984, 2000 and 2015 on crops/shrubs LULC class is presented in Fig. 4.

The occurrence of groundwater recharge in 2000 is similar to the study of Albhaisi et al. (2013) in South Africa between 1984 and 2009. Forest area later increased slightly between 2000 and 2015, which also increased groundwater recharge occurrence on forest LULC from 33.64% to 37.29%. About 4%

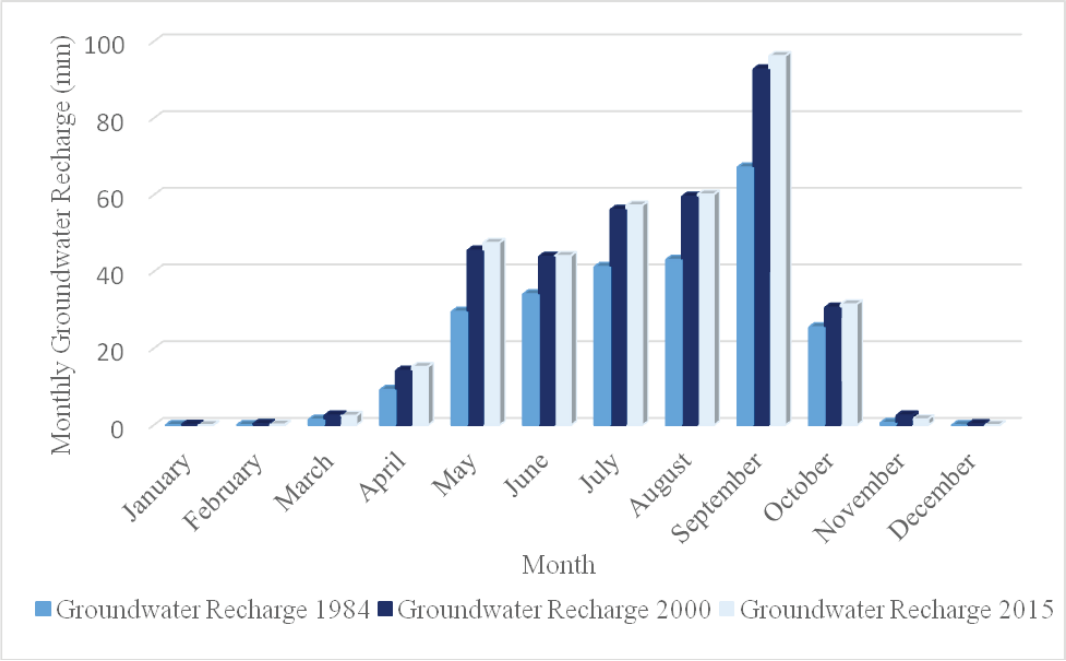

Fig. 4: Mean Monthly Recharge on Crop/Shrubs LULC Class

forest area decreased from 48.56% in 1984 to 33.64% in 2000. During this period, the forested area declined significantly as a consequence of human anthropogenic activities in the basin. As it was noted earlier that highest recharge was found in forest area, increased deforestation signals reduced recharge in the basin. The result obtained between 1984 and

increase in ground water recharge can be attributed to the slight increase in forest area that lead to reduced overland flow, more infiltration and percolation to the groundwater table to recharge the aquifer. Fig. 5 shows the monthly contribution of forest LULC class to groundwater recharge in 1984, 2000 and 2015 in the basin.

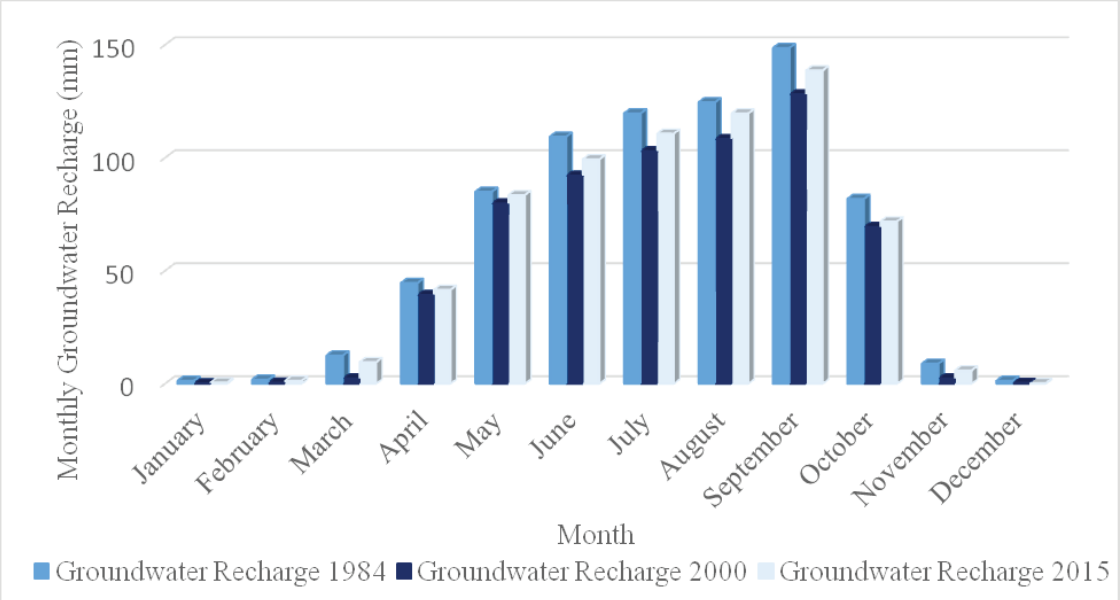

Fig. 5: Mean Monthly Recharge on Forest LULC Class

Groundwater recharge occurrence on bare surface increased from 20.69% to 24.76% between 1984 and 2000, while it increased further to 25.98% in 2015. This was an increase of 4.07% in groundwater recharge between 1984 and 2000, while it was 1.22% increase between 2000 and 2015. The relatively small increase rate of recharge occurrence on this LULC is as a result of less than 6.74% and 4% increase in areal coverage of bare surface between 1984 and 2000; and from 2000 to 2015, respectively. The minute increase may be attributed to the fact that bare land use tripled its areal extent of 1984 by the year 2008. The monthly occurrence of groundwater recharge in bare LULC class in 1984, 2000 and 2015 is presented in Fig. 6.

Wetland decreased from 1.55% in 1984 to 1.32% in 2000, which accounted for slight reduction in groundwater occurrence from 9.25% to 8.98%. Also, wetland decreased from 1.32% in 2000 to 0.24% in 2015, which was about 1.08% reduction in wetland between the period. The change in wetland leads to

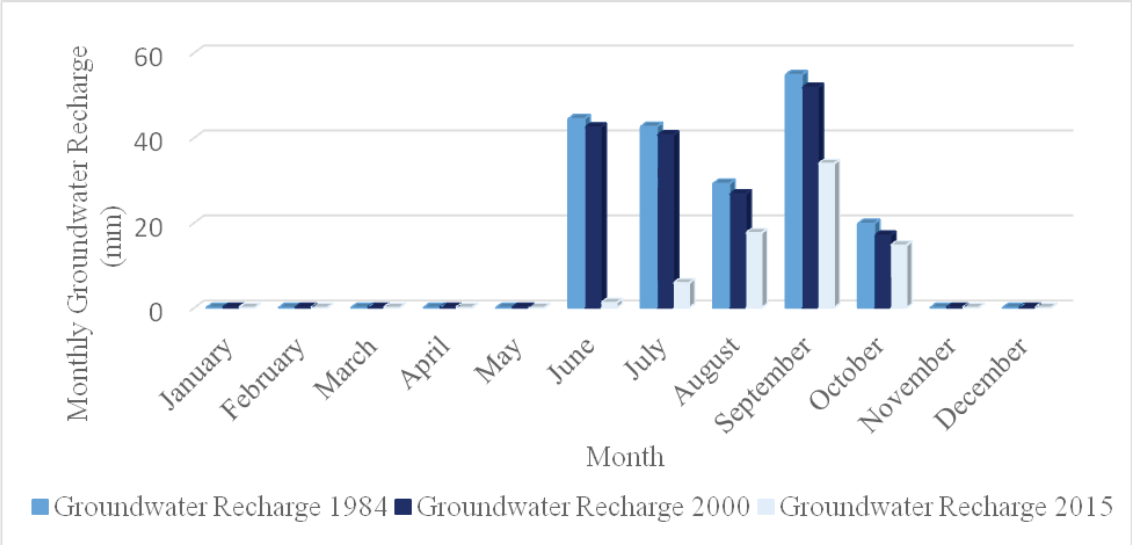

Fig. 6: Mean Monthly Recharge on Bare Surfaces LULC Class

in recharge occurrence on bare surface in Osun drainage is at variant with the observation of Albhaisi et al. (2013) in upper Berg catchment, South Africa, where groundwater recharge on bare LULC class increases significantly from 23% in 1984 to 64.7% in 2008. The significant increase observed in their study reduction in groundwater recharge on wetland from 8.93% in 2000 to 4.00% in 2015. This was slightly more than 50% reduction in groundwater recharge occurrence on wetland as a result of about 1.08% change in wetland LULC between 2000 and 2015. Monthly contribution of wetland LULC class to

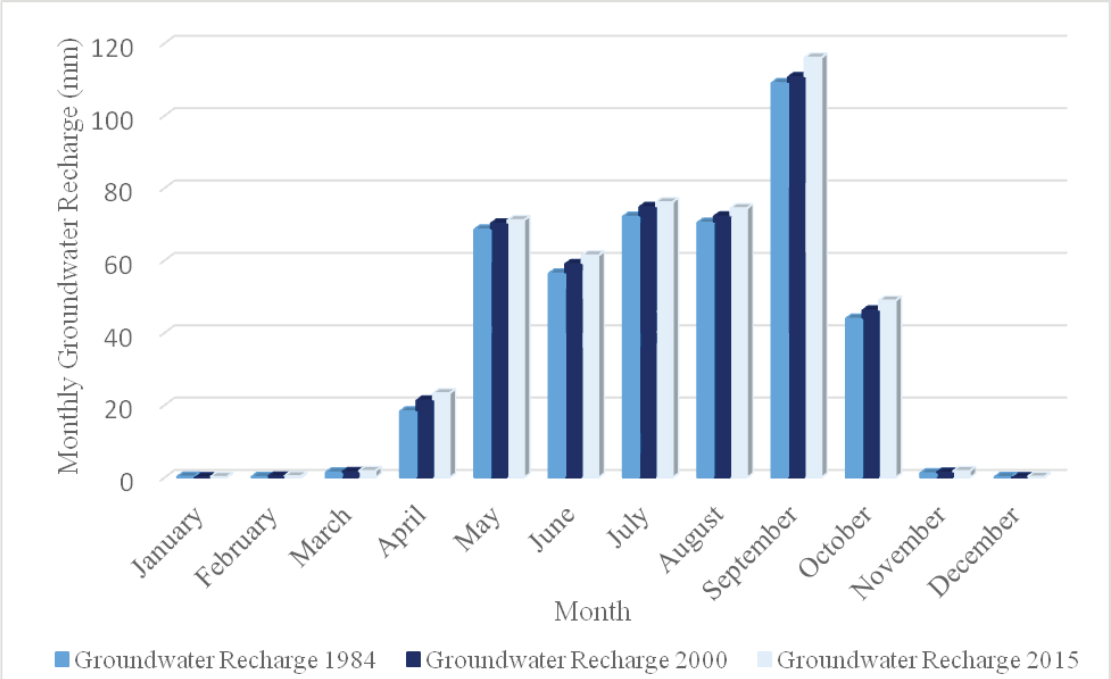

Fig. 7: Mean Monthly Recharge on Wetland LULC Class

groundwater recharge in 1984, 2000 and 2015 is presented in Fig. 7.

The mean annual groundwater recharge of the basin for the land use maps of 1984, 2000 and 2015 in the basin. As the main source of replenishment of the groundwater resources, groundwater recharge over time and space in a Basement complex aquifer determines the groundwater reserve. Hence, it can

Tab. 2: Overall Effect of LULC Change on Groundwater Recharge in the Entire Basin

Sn	*Years*	*Mean Annual Recharge*	*Change in Groundwater Recharge*		
			Period	mm	%
1.	1984	476.54	1984-2000	-65.40	-13.72
2.	2000	411.07	2000-2015	+18.99	+4.61
3.	2015	430.06	1984-2015	-46.48	-9.75

- signifies decrease in groundwater recharge
+ signifies increase in groundwater recharge

are 476.54, 411.07 and 430.06 mm/y, respectively is presented in Table 2. This shows that mean annual groundwater recharge decreased by 13.72% between 1984 and 2000, while it increased by 4.61% between 2000 and 2015. There was a general decrease of 9.75% in mean annual groundwater recharge between 1984 and 2015. As stated earlier, the forest area decreased from its areal extent of 5223.61 km^2 in 1984 to 2154.87 km^2 in 2015. The observed decrease in groundwater recharge can be attributed to a larger extent to the deforestation of the tropical rainforest under which highest groundwater recharge occurred be deduced that the groundwater reserve of the basin declined with about 10% between 1984 and 2015 as a result of change in LULC. The result is at variant with the observation of Albhaisi et al. (2013) in upper Berg catchment, South Africa where an increase in groundwater recharge of about 8% was observed between 1984 and 2008. The reason for the variance in results is that highest groundwater recharge occurrence was found in the forest area in this present study which has decreased to 21.71% by 2015, while, highest groundwater recharge occurred in bare land which has increased to 65% of the Berg catchment

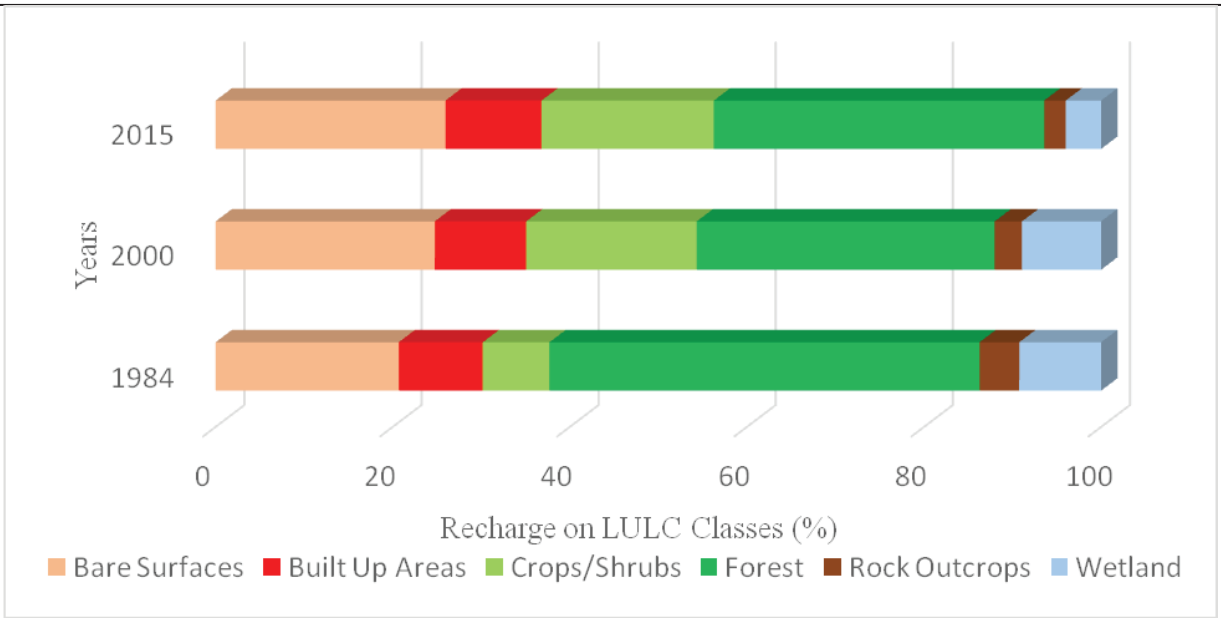

Fig. 8: Mean Annual Groundwater Recharge Occurrence on Different LULC Classes

by 2008.

The effect of LULC change on groundwater recharge in Osun drainage basin indicates that there are only little changes in recharge to groundwater system that can be associated to change in LULC. However, change in LULC have resulted to changes in recharge pattern in the basin. The reasons for the observed change in recharge pattern can be attributed to the fact that most often, change in LULC is a transition from one LULC class to another. The recharge pattern is influenced based on the amount and degree of transition taking place and the characteristics of the dominant LULC at a particular area of the basin. This correspond to Finch (2001) when he observed in a rural catchment of southern England that the mean annual groundwater recharge response to land cover change led to changes in the recharge pattern. Fig. 8 shows the percentages of the mean annual groundwater recharge occurrence on different LULC classes of 1984, 2000 and 2015 in Osun drainage basin.

Nevertheless, it is important to note that the percentage contribution of the seven LULC classes to groundwater recharge was based on the mean of groundwater recharge observed on each LULC class in the basin. Looking at it from the spatial perspective, a relatively higher change in recharge occurred on some LULC classes between 1984, 2000 and 2015. For example, the recharge amount occurrence on bare surface LULC in September 2000 in the northeastern and northcentral part of the basin in Oke Imesi, Efon Alaaye, Osogbo, Ede and Ilesha ranged between 118.45mm to 174.59mmm. In 2015, bare surface in the same part of the basin contributed groundwater recharge that ranged between 121.54mm to 138.61mm (Fig. 9). This revealed the change in spatial pattern of groundwater recharge as a result of change in LULC classes.

Conclusion. The effect of LULC change on groundwater recharge of Osun drainage basin was examined in this study. The contribution of each LULC class to groundwater recharge were examined for the years 1984, 2000 and 2015. The change in LULC between 1984, 2000 and 2015 influence only the recharge pattern but with little effect on the overall groundwater recharge in the basin. The groundwater recharge between 1984 and 2015 revealed a decrease of about 10%. This decrease was associated with decrease in forest area where larger percentage of groundwater recharge takes place in the basin. The continued deforestation of the forested area under which higher percentage of groundwater recharge occurred will not only pose a significant threat to groundwater reserve, but also to streamflow maintenance during dry months and the ecosystem of the basin in general. The average annual rate of change (decrease) in forest area for the 32-year period was 1.84%, which resulted to about 10% decrease in groundwater recharge for the period investigated. The 10% overall decline in groundwater recharge might become pronounced if the current rate of deforestation continues in the basin unabated. Therefore, a proper land use allocation and change strategy in sustainable management of groundwater resources becomes paramount. The afforestation in terms of planting of native trees that were lost through anthropogenic activities in the basin should be policy option for groundwater sustainability, because highest groundwater recharge occurred in forested area of the basin.

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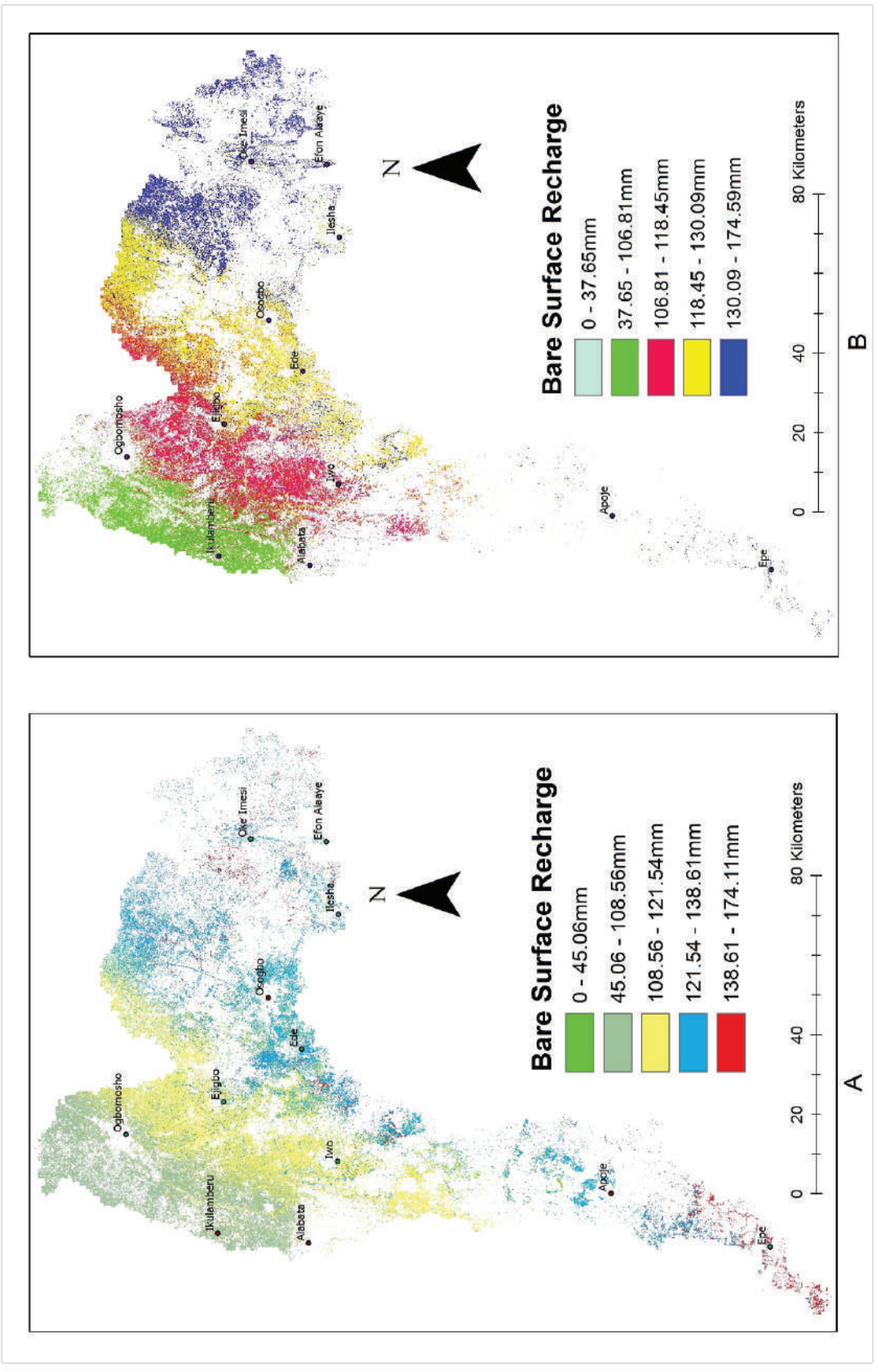

Fig. 9: (A) Bare Surface Recharge in September 2015 (B) Bare Surface Recharge in September 2000

are greatly appreciated.

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Peculiarities of geological and thermobaric conditions for the gas hydrate deposits occurence in the Black Sea and the prospects for their development

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Abstract. The actuality has been revealed of the necessity to attract the gas hydrate deposits of the Black Sea into industrial development as an alternative to traditional gas fields. This should be preceded by the identification and synthesis of geological and thermobaric peculiarities of their existence. It was noted that the gas hydrates formation occurs under certain thermobaric conditions, with the availability of a gas hydrate-forming agent, which is capable of hydrate formation, as well as a sufficient amount of water necessary to start the crystallization process. The gas hydrate accumulation typically does not occur in free space – in sea water, but in the massif of the sea bed rocks. The important role in the process of natural gas hydrates formation is assigned to thermobaric parameters, as well as to the properties and features of the geological environment, in which, actually, the process of hydrate formation and further hydrate accumulation occurs. It was noted that the source of formation and accumulation of the Black Sea gas hydrates is mainly catagenetic (deep) gas, but diagenetic gas also takes part in the process of gas hydrate deposits formation. The main component of natural gas hydrate deposits is methane and its homologs – ethane, propane, isobutane. The analysis has been made of geological and geophysical data and literature materials devoted to the study of the offshore area and the bottom of the Black Sea, as well as to the identification of gas hydrate deposits. It was established that in the offshore area the gas hydrate deposits with a heterogeneous structure dominate, that is, which comprises a certain proportion of aluminosilicate inclusions. It was noted that the Black Sea bottom sediments, beginning with the depths of 500 – 600 m, are gassy with methane, and a large sea part is favourable for hydrate formation at temperatures of +8...+9ºC and pressures from 7 to 20 MPa at different depths. The characteristics of gas hydrate deposits are provided, as well as requirements and aspects with regard to their industrialization and development. It is recommended to use the method of thermal influence on gas hydrate deposits, since, from an ecological point of view, it is the safest method which does not require additional water resources for its implementation, because water intake is carried out directly from the upper sea layers. A new classification of gas hydrate deposits with a heterogeneous structure has been developed, which is based on the content of rocks inclusions in gas hydrate, the classification feature of which is the amount of heat spent on the dissociation process.

Keywords: gas hydrate deposit, development, geological peculiarities, thermobaric conditions, dissociation, methane

Особливості геологічних та термобаричних умов існування газогідратних покладів Чорного моря, перспективи їх розробки

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Анотація. Розкрита актуальність необхідності залучення у промислове освоєння газогідратних родовищ Чорного моря як альтернативи традиційним газовим родовищам, чому повинно передувати виявлення та узагальнення геологічних і термобаричних особливостей їх існування. Відзначено, що формування газових гідратів відбувається за умов правильної комбінації температури і тиску, а також наявності газу-гідратоутворювача, здатного до гідратоутворення, та достатньої кількості води, необхідної для початку процесу кристалізації. Накопичення газового гідрату, як правило, відбувається не у вільному просторі – морській воді, а в масиві донних порід. Важлива роль у процесі формування природних газогідратів відведена термобаричним параметрам, а також властивостям і особливостям геологічного середовища, у якому, власне, й відбувається процес гідратоутворення та подальшого гідратонакопичення. Відзначено, що джерелом утворення та накопичення чорноморських газогідратів є переважно катагенетичний (глибинний) газ, але у процесі формування газогідратних покладів приймає участь

також і діагенетичний газ. Основним компонентом природних газогідратних покладів є метан та його гомологи – етан, пропан, ізобутан. Проведено аналіз геолого-геофізичних даних і літературних матеріалів, присвячених вивченню акваторії та дна Чорного моря, а також виявленню покладів газових гідратів. Встановлено, що в акваторії моря переважають газогідратні поклади неоднорідної структури, тобто такі, що містять певну частку алюмосилікатних включень. Відмічено, що чорноморські донні відкладення, починаючи з глибин 500 – 600 м, загазовані метаном, а значна частина моря сприятлива для гідратоутворення при температурах +8…+9°С і тиску від 7 до 20 МПа на різних глибинах. Висвітлені характеристики газогідратних покладів, вимоги та аспекти щодо їх промислового освоєння й розробки. Рекомендовано застосування методу теплового впливу на газогідратний поклад, оскільки з екологічної точки зору він є найбільш безпечним, не потребує залучення додаткових водних ресурсів для його реалізації, оскільки забір води здійснюється безпосередньо з верхніх однорідних шарів моря. Розроблено нову класифікацію газогідратних покладів неоднорідної структури, що базується на вмісті породних включень у газогідраті, класифікаційною ознакою якої є кількість тепла, що витрачається для протікання процесу дисоціації.

Ключові слова: газогідратний поклад, розробка, геологічні особливості, термобаричні умови, дисоціація, метан

Introduction. Every year in Ukraine there is a tendency to increase the fossil fuel consumption, the reduction of the reserves of coal, gas and oil in the traditional fields, fluctuation and constant increase in prices for imported hydrocarbon crude. Therefore, the search for and development of alternative energy sources is becoming increasingly important. In modern conditions it is necessary to modernize the structure of the oil-gas and coal state sectors, the changeover to new mining technologies (Falshtynskyi, Lozynskyi, Saik, Dychkovskyi, & Tabachenko, 2016; Falshtynskyi, Saik, Lozynskyi, Dychkovskyi, & Petlovanyi, 2018), as well as to use the nanotechnology-based solutions for the utilization of coalmine methane and its application as an energy source (Bondarenko, Kovalevs'ka, & Ganushevych, 2014; Hanushevych & Srivastava, 2017). By improving the development mechanisms of the energy segment of the country, it is possible to obtain additional energy products, in particular gas from coal deposits (Lozynskyi, Saik, Petlovanyi, Sai, & Malanchuk, 2018) and coal itself, which today is still an important energy source, despite the difficulties in the process of its extraction (Petlovanyi, Lozynskyi, Saik, & Sai, 2018). The development and introduction of gas production technologies by means of underground gasification of coal in complex mining and geological conditions is of special attention (Lozynskyi et al., 2018).

It is promising to obtain gas from gas hydrate deposits along with methane from coal deposits, shale gas and the gas from compressed sandstones. At the moment, the advanced countries of the world – India, Canada, China, Germany, Norway, USA, Japan, etc. – are engaged in the development of technologies for gas production from gas hydrates deposits. For Ukraine, the gas hydrate deposits of the Black Sea are of considerable interest, since gas reserves concentrated in the Ukrainian part (20 – 25 trillion m^3) exceed by several times the existing gas reserves of traditional fields. This will provide Ukraine with the energy source for several centuries, taking into account all the necessary needs of both the industrial state sector and the population. Moreover, the role of methane, possessed by our country, in the coming years may become decisive in the gas market redistribution.

A significant problem in the fuel and energy sector of Ukraine today is the lack of hydrocarbon crude, in particular natural gas, as well as the absence of a clearly developed strategy for exporting this energy source from abroad. Most Ukrainian deposits, both coal and gas, are in the final stage of development (Piwniak, Bondarenko, Salli, Pavlenko, & Dychkovskiy, 2007). Thus, for today, 85% of prospected oil reserves and 77% of gas reserves have been extracted. Ukraine belongs to a number of countries suffering from power shortages, that is, which satisfy the need for energy resources at the expense of domestic production less than by 50% (in gas by 23 – 25%, in oil by 12 – 15%). Our country is among the top five countries in terms of the use of imported natural gas per capita (Annual report…, 2016; Annual report…, 2017).

The conditions of natural gas production in Ukraine are constantly becoming more complicated due to the gradual depletion of the highest quality reserves and the growing share of lower quality reserves with a lower extraction potential and higher cost. For today, the gas production in the country is characterized by the following features: a high degree of the primary reserves depletion of major large fields; low rates of new reserves prospecting (the replacement rate of gas produced by new reserves over the past 20 years is below 100%); low quality of new reserves (reserves are divided between a large number of small fields and a significant part of these reserves are difficult to access); an increase in the depth of drilling in both existing and new fields (the average depth of drilling for gas production is about 3500 m, the maximum depth already exceeds 6000 m).

Given the above, it is possible to predict the next trend in the development of gas producing Ukrainian companies in the near future:

– development of new onshore fields, including small (1 – 5 billion m^3 of gas reserves) and sufficiently

small (up to 1 billion m^3 of gas reserves);

– development of the coastal Black and Azov Sea beds and river deltas;

– application of efficient drilling technologies at depths of 6000 – 7000 m);

– introduction of new technologies for gas production from alternative energy sources, which, first of all, include the Black Sea gas hydrate deposits.

The problem of energy supply can be fundamentally solved by involving the development of natural gas hydrate deposits of the Black Sea that are promising for use, since the gas reserves which are concentrated in the Ukrainian part by several times higher than the existing gas reserves of traditional fields. However, for this it is necessary to identify and summarize the geological and thermobaric peculiarities of the gas hydrate deposits occurrence, as well as to study the thermodynamic conditions of their formation for the further development of production directions and technologies.

Purpose of research – identification of geological and thermobaric peculiarities of formation and existence of the Black Sea gas hydrate deposits in order to improve the development of the directions and technologies of their production on the basis of systematization and generalization of the data of literary sources, information resources, own developments; development of gas hydrate deposits classification according to the rock inclusions content and the amount of thermal energy consumed on the gas hydrates dissociation.

Methods of research. To achieve the purpose set, an integrated approach was used in the work that includes processing and summarizing the literature and patent sources devoted to the study of peculiarities and thermobaric properties of gas hydrates, methods of the gas hydrate deposits development. The geological, geophysical, and climatic data on the conditions of hydrate accumulation and the formation of gas hydrate deposits in the Black Sea offshore area, as well as the distribution maps of the most promising areas of gas hydrate content were studied in detail. To generalize the gas hydrate deposits, their classification has been made according to the rock inclusions content and the energy spent for the dissociation of a deposit.

Research results. The peculiarities of gas hydrates formation and accumulation in natural conditions. The gas hydrates are solid ice-like crystalline compounds formed by water and natural gas molecules, in which water molecules are bonded to each other by hydrogen bonds and form scaffolds with large cavities inside (Gas hydrate, 2007). The ability of water to form gas hydrates is conditioned by the presence of hydrogen bonds in it. The chemical bonds are not formed between the molecules of gas and water. The guest-molecules (hydrate-forming agents) placed in lattice cells, stabilize the system, because in itself the crystalline host-lattice (water molecules) is thermodynamically metastable, when it is not filled with a minimal amount of gas molecules (Kvenvolden, 1994; Carroll, 2014).

The gas hydrates are formed under condition of low temperatures and high pressure (Fig. 1), provided

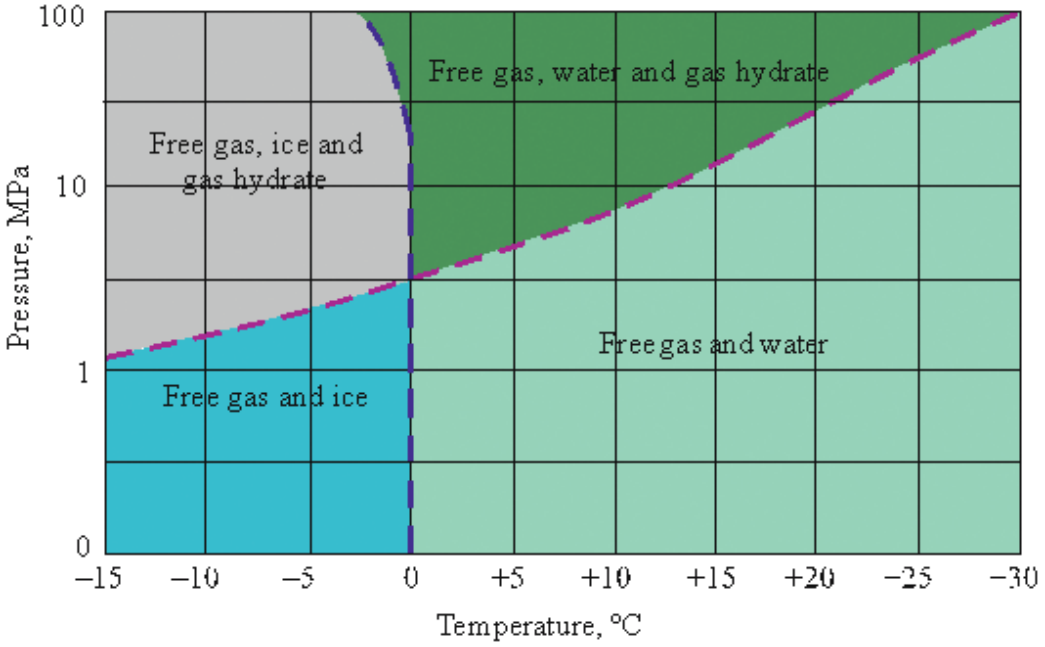

Fig. 1. Phase diagram of the gas hydrates existence: ----- the boundary line of "water – ice" phases; ----- the boundary line of "gas hydrate – free gas and water" phases

that there is a sufficient amount of hydrate-forming gas and water. The properties inherent in gas hydrates are unique. One volume of water, when changing to the hydrate state, binds up to 200 volumes of methane. Moreover, its specific volume increases by 26% (when freezing, the specific volume of water increases by 9%). 1 m^3 of methane hydrate at a pressure of 2.63 MPa and a temperature of 0°C contains 164 m^3 of gas. Therewith, the fraction of gas accounts for 0.2 m^3, for water – 0.8 m^3 (Makogon, 1997; Boswell, 2009).

During the periods of gas hydrates research, it has been found that such components of natural gas as CH_4, C_2H_6, C_3H_8, C_4H_{10}, CO_2, N_2, H_2S etc., form both individual and mixed hydrates (their composition includes several gases). However, it was not established the possibility of the gas hydrates formation of such gases as H_2, He and Ne (Bondarenko, Kovalevska, Astafiev, & Malova, 2018).

The gas hydrates formation occurs under the following conditions:

– appropriate temperature and pressure: as a rule, the formation of hydrates is caused by a rather low temperature and rather high pressure;

– gas hydrate-forming agent must be available: methane, ethane, propane, carbon dioxide or any other gas capable of hydrate formation;

– sufficient amount of water is required to start the hydrate formation process.

The gas hydrate accumulation, as a rule, does not occur in free space – in sea water, but in the massif of the sea bed rocks. The important role in the process of natural gas hydrates formation is assigned to the parameters of pressure and temperature, as well as to the properties and features of the medium, in which, actually, the process of hydrate formation and further hydrate accumulation occurs.

The thickness of gas hydrate strata ranges from hundreds of meters (when the deposits are located at a shall depth (less than 500 m)) to 1 km or more (when the deposits are located at great depths). A constant companion and source of natural gas hydrates formation can be free gas, located under the gas hydrate deposit. In some areas of bottom sediments, its concentration is so high that it begins to penetrate into the free spaces between the rock particles. As the gas hydrates are accumulated in sedimentary rocks, these rocks become impermeable. An enclosed space is formed, capable of self-compacting, in which the gas is accumulated which tends to rise upwards. The more free gas penetrates into the hydrate formation zone, the stronger the gas hydrate deposit becomes. After complete saturation of the gas hydrate stratum, the free gas can be accumulated already under it.

The lower line of occurring the gas hydrate deposits is determined by the geothermal gradient in the bottom rocks. About 99% of gas hydrate reserves are located in the offshore areas of the seas and oceans. In the onshore conditions, there is also the necessary thermobaric combination of pressure and temperature sufficient for the formation of natural gas hydrates and its homologs. It should be noted that in the continental rocks there is less water and less free space in which crystalline hydrates are formed (Makogon, 2010a).

It has been established that gas hydrate accumulations in mine rocks exist in the form of the following cryohydrate structures: massive (in sandy soils); porphyry (in sandy-loam soils); lenticular-schlieren (in clay soils).

The gas hydrates may be a cement or simply fill in the voids without cementing the sediment grains. Strengthening sedimentary rocks occurs due to the presence of hydrates in them, performing the role of cement. Also, the gas hydrates can exist in the pore space, without having a noticeable influence on the stiffness and strength of sedimentary rocks. The gas hydrates formation in the seas in the conditions of bottom rocks suggests the filling of the existing voids not with water, but with a solid gas hydrate skeleton (Pedchenko & Pedchenko, 2017).

To assess the gas hydrates energy potential, it is important to determine the possible variants of their location in the sedimentary mass and to determine the properties of hydrate-bearing strata. Having analysed the existing data on the findings of gas hydrates in the Earth's interior, a conclusion can be made that gas hydrates exist in rocks in the form of small inclusions, beams, veinlets, and massive strata.

The gas hydrates formation in sedimentary deposits occurs according to two different variants of hydrate accumulation:

– the first, when gas hydrates are formed and accumulated at contacts of the rock particles, which leads to cementation of the sedimentary deposits skeleton;

– the second, when the gas hydrates formation occurs directly in the cavities and pores. According to this variant, it is obvious that hydrates have almost no influence on the connection of rock particles, which leads to the sedimentary mass compaction.

Geological and thermobaric conditions of hydrate formation, availability of gas hydrates in the Black Sea. The issues of deposits development, related directly to the consideration of geological structure, are constantly actual for all types of min-

erals (Petlovanyi, 2016; Maksymova & Kostrytska, 2018; Petlovanyi, Lozynskyi, Zubko, Saik, & Sai, 2019). The existing technologies for identifying the gas hydrate deposits are based on using the properties of hydrates and hydrate-saturated rocks. The most widely used method is standard and high-frequency seismology, according to data of which, the position of the lower boundary of hydrate-saturated rocks is determined with an availability of free gas under the hydrate-saturated strata – Bottom Simulation Reflector (BSR) boundary (Thakur & Rajput, 2010).

The study of the conditions for gas hydrates formation, their stable existence and properties in natural environment makes possible to confidently predict their occurrence in different onshore areas, in the World Ocean, and in particular in the Black Sea. The Black Sea offshore area is characterized by the occurrence of gas hydrate deposits, the thickness of which, according to geologists and seismic survey results, reaches at an average of 1000 m from the sea bed surface. The Ukrainian part of the sea has methane gas resources, which can be extracted from the gas hydrate deposits located directly opposite the Crimean Peninsula, about 20 – 25 trillion m. The total projected gas resources throughout the Black Sea are at least 100 trillion m^3, based on the results of drilling and the studied cores analysis (1988 – 1989) (Korsakov, Byakov, & Stupak, 1989; Gas hydrates…, 1990).

The Black Sea is one of the largest and deepest seas. The average sea depth is 1300 m. The maximum depth, according to different sources, based on the echo-sounding survey data, is in the range of 2210 – 2258 m. The river streams inflowing into the sea have a limited runoff through the narrow Bosphorus Strait, with 32 m in depth and about 750 m in width. The mixing of water is determined only by winds to shall depths and low-powered seepages located at depths up to 700 m.

The bottom temperatures are around +9ºC. Plankton can exist only in the upper 200-meter layer of water, which is mixed, and contains dissolved oxygen. At great depths, the water is saturated with hydrogen sulfide, where only anaerobic bacteria that generate hydrogen sulfide can exist. The vertical water circulation is practically absent. There is also no migration of dissolved gases, generated in the upper "living" water layer, into the deep hydrogen sulfide layer.

The Black Sea uniqueness is as follows:

– it is the world's largest meromictic reservoir, in which almost stagnant water column has been accumulated and that does not circulate;

– it is the relatively young "closed" sea (pool isolation affected the water saturation with hydrogen sulfide, as well as the generation and dynamics of hydrocarbons);

– absence of life at depths greater than 200 m, except sulphur bacteria;

– giant methane reservoir.

The modern Black Sea basin is a part of the large Alpine orogenic belt. It is the north-eastern segment of the Mediterranean mobile belt. In the north, these two depressions border on the southern edge of the East European Platform, in the east they border on the zone of the Taman dome structures, which are the western extension of the Caucasian orogen, in the south – the Anatolian fold structures, in the west – the structures of the Mysia Plate and the Dobruji mountain structures. The north-western part of the Black Sea offshore is a tectonic depression (trough) of the Northern Black Sea region, which arose in the late Maykop time between Dobruji in the west and the Crimean Peninsula in the east. In the south, the depression is opened toward the large Black Sea depression, and in the north it is deeply embedded within the East European Platform (Nikishin et al., 2015; Vespremeanu & Golumbeanu, 2017).

In the offshore area of the Black Sea, there are three main geomorphological elements at the bottom: the shelf, the continental slope, and the deepwater depression. The Black Sea shelf is the coastal part of the sea bed to depths of 90 – 110 m. The geological shelf structures are a continuation of the onshore structures. The shelf, or continental shelf, occupies 25% of the sea offshore area. The continental slope corresponds to a narrow zone of steep bend of the sea bed from the outer shelf to depths of 1830 m and occupies about 40% of the offshore area. The deep-sea depression of the Black Sea (about 35% of the offshore area) is a flat accumulative plain that extends from the west to the east in the oval form and is slightly inclined to the south. Its bottom is almost flat, it is characterized by a relief with small protuberances, the inclination angles vary in the range of 0 to 1°. There were not found the large forms of submarine relief according to the echometry surveys data. The depths everywhere are over 2000 m.

The analysis of thermobaric conditions within the deepwater area of the Black Sea Depression gives every reason to assert that the available temperature and pressure parameters at the sea depths of 500 – 750 m are optimal for the gas hydrate deposits formation under such conditions (97/01843 Thermodynamic conditions…, 1997; Demirbas, 2009; Shnyukov, 2013). The lower boundary of these deposits occurrence is 400 – 500 m below the sea bed

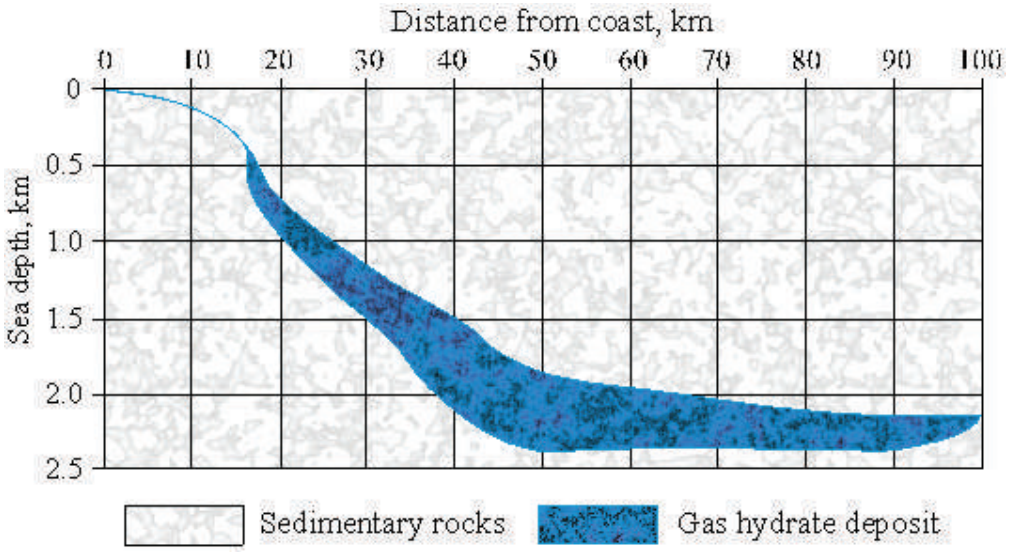

Fig. 2. The zone of gas hydrates formation in the Black Sea (Makogon, 2010b)

and depends on the sea depth. In Fig. 2, there is a rock stratum of the gas hydrate deposits occurrence, which is located to the south of the Crimean Peninsula.

During the research process aimed at studying the heat flux distribution in the Black Sea depression, A.D. Duchkov and S.A. Kazantsev discovered a wide and lengthy zone of reduced (almost twice) heat flux, which is stretched across the entire offshore area from west to east, and the similar anomaly in the northern Black Sea part, opposite the Kerch Strait (Duchkov & Kazantsev, 1988). With account of these data, the thickness of hydrate formation zone for these areas can reach 1000 – 1200 m, which is confirmed by the results of seismic operations by means of the common depth point method in the Western Black Sea depression. Therefore, it can be stated that the hydrate formation zone covers the entire deepwater depression and a significant part of the continental slope.

For the first time, the possibility of the natural gas hydrates availability in the bottom Black Sea sediments was expressed by A.G. Efremova and B.P. Zhizhchenko during the expeditions, when in one of the soil columns lifted from a depth of about 2000 m (location was not indicated), white, frost-like microcrystalline growths were found inside large voids at 6.5 m from the surface, which disappeared quickly when being lifted on the ship's deck. Then it was suggested a possible gas hydrate origin of the detected crystals (Efremova & Zhizhchenko, 1974).

In 1988, the Computing Center of the Siberian Branch of the Academy of Sciences of the USSR and the All-Union Scientific Research Institute of Oceanology, the USSR Ministry of Geology, conducted a special expedition in the Black Sea aimed at identifying gas hydrates (21 cruise of the research vessel "Evpatoria") in the deepwater part of the Sorokin Trough. During the expedition, it was found and partially studied the accumulation of gas hydrates associated with diapir structure, located to the south of the Crimean Peninsula at water depths down to 1400 – 2200 m. The most effective manifestation was noted in clay breccia at a depth of about 2000 m in a column interval of 70 cm, where a monomineral hydrate sample with 8 cm in length and 12 cm in diameter was obtained, which corresponded to the internal diameter of the pipe. In other samples, thin (3 – 5 mm) but lengthy veinlets were noted. The total hydrate content was about 10%, the rest was rocks. In the gas hydrate composition methane prevailed (97 – 98%), ethane content was 0.02 – 0.4%, carbon dioxide – 0.5 – 0.9%, hydrogen sulfide – 0.25% (Ginsburg, Kremlev, & Grigor'yev, 1989).

The first exploratory seismic surveys in the Black Sea, performed by the SEVRMORGEO of the Russian Academy of Sciences in 1988 discovered 5 gas hydrate areas. The most promising area is located 20 km to south of Yalta. This is a large area where search and exploration of gas hydrate deposits should be focused. Other promising areas are located in the waters of Russia, Turkey and Georgia. In 1989, gas hydrates were discovered within one of the zones of diapir-like folds' development and local disturbances in the central part of the sea, 90 km south of Saryich Cape.

During the cruise of the research vessel "Gelendzhik", under the ANAXIPROBE/TTR6 program in 1996, gas hydrates were also discovered in the Sorokin Trough and the central part of the Black Sea. In the course of work, three different types of gas hydrate structures were described: layers of massive

gas hydrates (as pure hydrated ice, so with a small proportion of rocks inclusions); gas hydrates massive pieces with irregular shape, randomly distributed in the mud-volcano breccia near the rock fragments; thin lenses and hydrate layers, oriented in parallel to the bedding of sediments and to the sea bed. The data obtained during the expedition allowed the authors to conclude that gas hydrates are widely distributed in the studied area and in large volumes (Ivanov, Limonov, & Woodside, 1998).

In 2001, the studies on gas hydrates were carried out again in the Black Sea. In the course of work, gas hydrates were found in sediments in the Sorokin Trough and were the plates of 2 – 3 mm thick and more than 5 cm in diameter. Also, the gas hydrates have been found in sediments of the north-western Black Sea part. By their structure, they were very porous and brittle by sense of touch, up to several centimeters in size. Based on visual observations, it was possible to distinguish two types of sedimentary hydrate-forming textures. The type of texture, when gas hydrates are more or less uniformly distributed in sediments, can be attributed to porphyry or massive type. In addition, some gas hydrate samples were oriented along the sedimentary stratification of the enclosing sediments.

An important issue that determines the approach to the study of patterns of gas hydrates formation in the subsoil, is the question of the sources of hydrocarbon gases and how they enter into the zone of hydrate formation. Some researchers consider that the genetic factor is no less important in the formation of gas hydrate deposits than the thermodynamic one. The classification is based on the concept of the main geological models of natural gas hydrate formation – cryogenic, eustatic, sedimentary, filterogenic and diagenetic. For the Black Sea Depression conditions, the most probable are sedimentary, filterogenic and diagenetic types of gas hydrate deposits.

One of the sources can be gaseous products of biochemical conversion of organic matter (methane, hydrogen sulfide, carbon dioxide, etc.). Therewith, some scientists admit the presence of gases inflow that saturate the pore water to levels sufficient for the crystalline hydrates formation. When gas-saturated deposits being submerged within the hydrate formation zone, primary gas hydrate deposits are formed, which fill the sea bed along with bottom rocks.

A.O. Trofimuk believes that gas hydrates can be accumulated in the stratal waters under the conditions of their considerable undersaturation with gas and at available appropriate thermobaric conditions. In this case, it is an important fact that the presence of lithological rocks is not necessary for the deposit formation, since the layer which contains the gas hydrates, becomes almost impermeable for gaseous hydrocarbons when filling 65 – 70% voids volume with hydrates. This finding is very important for assessing the potential of the Black Sea Depression, since the possibility of formation in the bottom sediments (300 – 500 m below the bottom) a layer impermeable to gases, allows to consider a wide range of objects, and increases significantly the potential of the entire sedimentary cover (Trofimuk, Cherskiy, Makagon, & Tsarev, 1973).

Another important source of hydrocarbon gases is migration flows of catagenetic natural gases entering the hydrate formation zone through tectonic (fractures, crushing zones) and lithological channels from the main oil-gas formation zone. An important factor that initiates the migration processes, is the neotectonic activity of the earth's crust, which is characteristic of the Black Sea region.

The thickness of the hydrate formation zone essentially depends on the value of the temperature gradient and heat flux. In zones with low heat flux (25 – 30 mW/m^2), the thickness of hydrate formation stratum can be 350 – 400 m, with an increase in heat flux up to 40 mW/m^2, it decreases to 200 – 250 m, and at heat flux values of 60 mW/m^2 and more – it is reduced to tens of meters. In zones with abnormally high heat fluxes (80 – 100 mW/m^2), the gas hydrate stratum is most likely absent (Starostenko, Shnyukov, Kobolev, Rusakov, & Kutas, 2008).

The Black Sea bottom sediments, starting at depths of 500 – 600 m, are gassy with methane. The powerful gas emissions in the form of numerous seepages, fountains, mud volcanoes were recorded almost along the entire Black Sea perimeter. Currently, about 4000 gas flames have been discovered, localized on the periphery in the Black Sea offshore, in particular, in the north-west of the Black Sea, the Bulgarian, Kerch-Taman shelves, along the coast of the Caucasus and on the continental slope and shelf of Turkey.

As mentioned above, the source for the Black Sea gas hydrates formation and accumulation is predominantly catagenetic (deep) gas, but diagenetic methane is also involved in the formation of gas hydrate deposits. The main component of natural gas hydrate deposits is methane and its homologs – ethane, propane, isobutane. Also the gas, which is released after the decomposition of gas hydrates, contains steam-like gases – pentane and hexane. They are not included into the gas hydrates structure, but are probably adsorbed by the surface. The proportion of methane is 93.3 – 98.9%, the proportion of its homo-

logs is 1.1 – 6.7%.

Some gas hydrates contain 100% of methane. The performed studies have shown the presence not only of hydrocarbon gases in the gas hydrate deposits, but also of nitrogen, carbon dioxide and hydrogen sulphide. However, their proportion is extremely low (Makogon, 2010a).

The gas hydrates have also been found at depths of 2000 m, which indicates the deep origin of the gas contained in gas hydrate deposits. This made possible to identify two main types of gas hydrate deposits in the Black Sea deepwater areas for O.S. Gorshkov and his colleagues (Gorshkov, Meysner, & Tugolesov, 1992):

– gas hydrates which are connected with migration gases that go through tectonic disturbances and mud volcanoes;

formation zones are localized in the Black Sea mainly in the quaternary deposits, which reach a thickness of 1 – 3 km, in the Sorokin Trough occasionally even in neogene. The criterion for the availability of gas hydrates in sediments on seismic profiles is a specific imaging, which displays the bottom configuration.

According to the regional seismic profiles by a grid of 25×25 km, made by the SEVRMORGEO association, a significant distribution of gas hydrates deposits within the deepwater Black Sea part has been set, and a map of prospects for gas content in the hydrate formation zone has been constructed (Fig. 3) (Korsakov, Byakov, & Stupak, 1989; Bondarenko, Ganushevych, Sai, & Tyshchenko, 2011).

According to this map, the most promising are the central, northeastern and northern parts of the Black Sea, where a special attention should be focused on

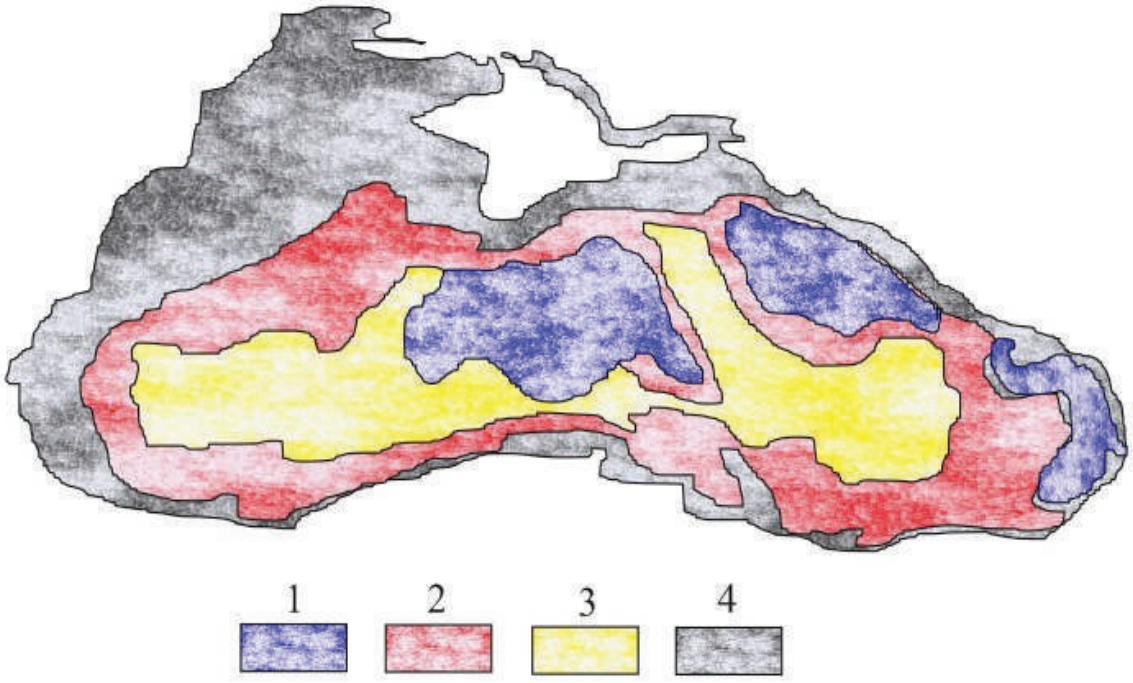

Fig. 3. The map of prospects for gas content in the hydrate formation zones of the Black Sea Depression: 1 – highly promising zones of hydrate formation; 2 – promising zones of hydrate formation; 3 – little promising zones of hydrate formation; 4 – unpromising zones of hydrate formation

– gas hydrates of river fans.

The predicting assessment of the gas content potential in the Black Sea subsoil is most clearly expressed in the work of O.D. Korsakov, O.Yu. Byakov, S.M. Stupak (Korsakov, Byakov, & Stupak, 1989). For hydrate formation, the situation is favorable practically in the whole deepwater Black Sea Depression. The regional geophysical studies of these authors have provided a spatial pattern of the natural gas hydrates distribution in the Black Sea. The hydrate

the technologies development of gas extraction out of the gas hydrate deposits (Bondarenko, Maksymova, Ganushevych, & Sai, 2013; Bondarenko, Sai, Prokopenko, & Zhuravlov, 2018).

Given the above, and based on the results of their own research (Bondarenko, Svietkina, & Sai, 2018), the authors have made a conclusion that in the Black Sea offshore, the gas hydrate deposits predominate of heterogeneous structure, that is comprising a certain proportion of aluminosilicate inclusions. This proves

the fact that the limous bottom compounds practically are aluminosilicates of different composition with an admixture of metal oxides – iron, magnesium, titanium, calcium, etc. Although in the natural state, clay minerals have low adsorption and catalytic activity, they can be activated through ion exchange, hence, this makes it possible to regulate their porous structure. Such activation leads to a sudden growth of the surface and mesopores volume, which is conditioned by the formation of amorphous silica, which has pores that are available not only for water molecules, but also for hydrocarbons.

The Black Sea waters, as a rule, are not prone to freezing. The average water temperature in the sea does not fall below +7...+8ºC, in winter it rises from –0.5 to 0ºC in the coastal areas of the northwestern part, to +7...+8ºC – in the central, and +9...+10ºC – in the southeastern part of the sea. In summer, the water surface layer is warmed up to +23…+26ºC. The average water temperature by horizons is shown in Table 1.

Table 1. The average values of the Black Sea water temperature by horizons, °C

Horizon, m	January	February	March	April	May	June	July	August	Septem-ber	October	Novem-ber	Decem-ber
0	+7.7	+7.2	+6.8	+9.2	+14.1	+19.8	+22.8	+23.8	+20.8	+18.7	+11.7	+9.5
10	+7.7	+7.1	+6.8	+9.0	+12.8	+18.5	+21.8	+23.6	+20.7	+18.6	+11.8	+9.6
20	+7.7	+7.0	+6.7	+8.4	+10.2	+11.9	+12.2	+13.6	+19.2	+17.9	+11.6	+9.6
30	+7.7	+7.0	+6.7	+7.7	+7.9	+7.8	+8.5	+9.0	+9.1	+12.0	+10.4	+9.2
50	+7.6	+7.4	+7.3	+7.6	+7.4	+7.3	+7.4	+7.6	+7.2	+8.0	+7.6	+7.8
100	+8.3	+8.3	+8.3	+8.3	+8.3	+8.3	+8.3	+8.3	+8.3	+8.3	+8.3	+8.3
200	+8.5	+8.5	+8.5	+8.5	+8.5	+8.5	+8.5	+8.5	+8.5	+8.5	+8.5	+8.5
500	+8.9	+8.9	+8.9	+8.9	+8.9	+8.9	+8.9	+8.9	+8.9	+8.9	+8.9	+8.9
700	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0
1000	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0
1500	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0	+9.0

Beginning with the horizons of 150 – 200 m, the salt content and temperature of water slowly increase to the bottom caused by the influence of more salt and warm waters flowing into the deep layers. In the vertical hydrological structure of the Black Sea waters, the following main components are distinguished:

– a homogeneous upper layer and seasonal (summer) thermocline layer, mainly related to the process of windy mixing and the summer cycle of heat flux through the sea surface;

– a cold intermediate layer with a minimum temperature at a depth, which in the northwest and northeast of the sea occurs as a result of autumn-winter convection, and in other areas is formed mainly by the transfer of cold water by currents;

– constant halocline – a layer of maximum salt content increase with a depth, which is located in the contact zone of the upper (Black Sea) and deep (Marmara Sea) water masses;

– deep layer – from 200 m to the bottom, where there are no seasonal changes in hydrological characteristics, and their spatial distribution is sufficiently uniform.

Aspects of criteria choice for the gas hydrate deposits development. The choice and substantiation of the technological schemes and the appropriate rational parameters of the gas hydrate deposits development should include the implementation of several stages and be carried out for the conditions of each specific field (Bondarenko, Maksymova, & Koval, 2013; Maksymova, 2018). The gas hydrate deposits of high priority and that suitable for development can be chosen according to the principle proposed in the work (Petlovanyi & Medianyk, 2018). Taking into account the peculiarities of gas production from gas hydrates and guided by the Rules for the development of oil and gas fields, as well as by the Law of Ukraine "On Oil and Gas", it is obvious that the gas hydrate field should be characterized as follows (Zakon Ukrainy…, 2018):

1. According to the geological structure complexity of the productive gas hydrate horizons:

– fields with a complex geological structure, which have a variable nature of productive horizons – lithological composition, reservoir characteristics, etc.;

– fields with a simple geological structure, productive deposits of which are characterized by relative continuity of lithological composition, reservoir characteristics and productive horizons over the entire deposit area.

2. By the number of developed deposits:

– single-layered, when there is only one deposit or all deposits are combined into one object of development;

– multi-layered, when several objects are allocated for development.

3. By thermobaric parameters.

4. According to the degree of deposit saturation with gas hydrates, depending on the rocks porosity, the hydrate density, the thermodynamic characteristics and the range of development depths.

5. According to the designed maximum possible operating specific productivity index of future boreholes: decreased, low, medium and high specific productivity indeces.

6. By the value of the initial strata pressure: low, medium and high pressure.

For gas hydrate field, which is accepted for development, the following steps should be performed:

– a preliminary detailed exploration of the place of deposit occurrence, assessment of gas reserves, which are in the form of gas hydrates;

– determining the distinct boundaries of the field, density and porosity of host rocks;

– performance of full-scaled tests and studies in several boreholes in order to obtain the main distinguishing deposit characteristics;

– identification of structural and geometric peculiarities of the deposit structure;

– establishment of the basic characteristics of productive strata: thickness, porosity, permeability, gas recovery factor, thermal conductivity coefficient and thermal diffusivity of host rocks.

Designing the development of a selected gas hydrate field provides for a preliminary core sampling from productive horizons in boreholes planned by the exploration project. The purpose of continuous or selective withdrawal of cores is to study the totality of the physical and chemical properties of productive deposits and the inclusions contained in them.

A complete performance of industrial geophysical research in all exploration boreholes, including the establishment of azimuth and curvature of the wellbore, is an integral component before the beginning of the gas hydrate fields development. In specially prepared boreholes, it is necessary to determine the geothermic gradient value for each selected exploration field area. Types and scope of geological and industrial research in the drilling of boreholes are established and approved by the Program of Exploration and Commercial-Test Production of the field.

The methods for gas production and classification of gas hydrate deposits according to the content of rocks inclusion and energy consumption during their dissociation. The technologies for the gas hydrate fields development and the recovery of methane gas from them are connected with the physical and chemical properties of these clathrate compounds, and based on the dissociation, by which the gas hydrates are dissociated into gas and water (Bondarenko, Ganushevych, & Sai, 2012). To release the gas contained in hydrates, the equilibrium parameters of their stable existence can be shifted. At present, there are three main methods of gas production from gas hydrates (Processes for methane…, 2010; Rogers, 2015):

– thermal treatment method based on deposit heating;

– depressive method which is in reducing the pressure in the gas hydrate;

– substitution method or adding chemicals that are catalyst agents for the dissociation process of gas hydrate deposit.

Table 2 shows the existing subtypes of the main methods for gas extraction from gas hydrate deposits.

Table 2. Methods for the gas hydrate deposits development and the natural gas extraction from them

Dissociation method	Subtypes of the method
Thermal treatment method	Method of heating with the use of injection of heat-transfer medium
	Hot water circulation method
	Method of gas hydrate deposit decomposition with the use of steam, heated gas or liquid
Depressive influence method	Method of depressurization by reducing the pressure around the borehole
	The method of reducing the water or free gas pressure on gas hydrate after their partial pumping out

The thermal treatment method for gas hydrate deposits development is based on the supply of heat inside the hydrate crystalline structure to increase its temperature, which accelerates the dissociation process of crystalline hydrates. This method is suitable for the productive deposits development that have a high degree of hydrate saturation. But precisely this deposits are widely spread in the Black Sea offshore. The thermal treatment method is the safest from an environmental point of view. It does not require additional water resources for its implementation, since water intake is carried out directly from the homogeneous upper sea layers.

The temperature values of the Black Sea water by horizons, starting from clay 100 m, does not fall below +8ºC (Table 1), and in summer the average temperature of the seasonal thermocline fluctuates at the level of +20ºC, which is an additional advantage and reduces the heat consumption for heating when applying the thermal treatment method of deposit development. Also, the thermal influence method, in contrast to the depressive one, excludes the possibility of hydrates technogenic formation in the bottom-hole zone, which, in turn, could require the introduction of inhibitors to eliminate hydrate blocks in the wellbore.

To substantiate the parameters of the development method of gas hydrate fields, it is advisable to systematize and group the fields due to the diversity of their geological, morphological and thermodynamic properties in order to determine the limiting boundaries of the rational use of the thermal influence method or the choice of another, most optimal method.

The generalized data on the conditions for gas hydrates formation and existence, which are based on the existing results of the analysis of drilled borehole cores, give reason to the authors to conclude that gas hydrates are contained in the Black Sea bottom sediments at an appropriate temperature and pressure parameters corresponding to the conditions of stable existence of gas hydrate deposits, not only in a form of pure hydrate stratum, and, more often, with rock aluminosilicate inclusions, which makes the structure of the deposit heterogeneous. Thus, the efficiency of the decomposition process of gas hydrate deposits with a variable proportion of aluminosilicate inclusions depends on the amount of thermal energy consumed to produce 1000 m^3 of gas (Bondarenko & Sai, 2018). These calculations, performed by the authors in the process of research, made it possible to determine the volume of decomposition zones of heterogeneous gas hydrate deposits and the output of methane gas from the proportion of rocks inclusions.

With account of previous own developments and peculiarities of hydrate accumulation in the Black Sea sediments, the authors have developed a classification of gas hydrate deposits, which is based on the content of rocks inclusions in these deposits. The classification is based on energy consumption in the gas hydrate deposits development to produce 1000 m^3 of methane gas. Thus, it is proposed to divide gas hydrate deposits into 4 classes depending on the proportion of rocks inclusions in the gas hydrate massif (Table 3).

Table 3. Classification of gas hydrate deposits by energy consumption

Class	Naming	Proportion of rocks inclusions (η), %	Amount of thermal energy to produce 1000 m^3 of methane gas
I	Almost homogeneous	≤ 15	≤ 3007.25
II	Heterogeneous	≤ 30	≤ 3269.23
III	Much heterogeneous	≤ 45	≤ 3549.14
IV	Considerable heterogeneous	≤ 60	≤ 4764.42

I heterogeneity class. It is assumed that this type of gas hydrate deposits contains up to 15% of inclusions, but they will not influence significantly on the conditions of development. Such deposits are considered to be almost homogeneous, since the number of inclusions does not exceed a certain limit, after which they cannot be considered as structure-forming inclusions of gas hydrate. In this case, the gas hydrate itself becomes the main rock-forming element and exists as a homogeneous gas hydrate structure.

II heterogeneity class. This type of gas hydrate deposits is most common in nature, and contains in its composition from 16 to 30% of rocks inclusions. It is characterized by intense gas recovery factor during the gas hydrate dissociation. The deposits are gas hydrate massifs with significant thickness (sometimes up to 400 m).

III heterogeneity class. The gas recovery factor in the development of this type of gas hydrate deposits

is slightly less than in the development of the II class deposits, since they contain from 31 to 45% of rock minerals inclusions.

IV heterogeneity class. The content of inclusions for this type of gas hydrate deposits varies from 46 to 60%. It is obvious that almost half of the gas hydrate deposit contains rock particles. The gas recovery factor in the process of this class development of gas hydrate deposits will be the lowest.

Based on the above classification, the development of gas hydrate deposits of I – III classes is the most expedient, since the value of their gas recovery factor is significantly higher than that of deposits classified as IV class. Nevertheless, the production of gas from these deposits is also possible with account of the appropriate development parameters.

Conclusions. In view of the limited reserves of hydrocarbon energy sources in the Ukraine's interior, the significant dependence on import of these resources from other countries, fluctuations in market prices for society, it is extremely important to develop strategies for developing the production of alternative fuel sources. Such a type is gas hydrate deposits, in which the methane gas reserves significantly exceed the existing gas reserves of traditional fields, and this could provide Ukraine with a source of energy for several centuries, taking into account all the necessary needs of both the industrial state sector and the population. Moreover, the role of methane, possessed by our country, in the coming years may become decisive in the gas market redistribution.

The analysis has been made of geological and geophysical data and literature materials devoted to the study of the offshore area and the bottom of the Black Sea, as well as to the identification of gas hydrate deposits. It was set that the Black Sea bottom sediments, beginning with the depths of 500 – 600 m, are gassy with methane, and a large sea part is favourable for hydrate formation. As a result, a productive zone of gas hydrate reserves has been formed, which are assessed by researchers at 100 trillion m^3, and in the Ukrainian part – 20 – 25% of these reserves. It was noted that the gas hydrates formation occurs at the appropriate combination of temperature and pressure, the availability of a gas hydrate-forming agent and a sufficient amount of water necessary to start the crystallization process. The water temperature, where the hydrates formation is noted (below 500 m) is +8ºC, and the pressure at this depth is 6 – 8 MPa. The source of formation and accumulation of the Black Sea gas hydrates is mainly catagenetic (deep) gas, but diagenetic gas also takes part in the process of gas hydrate deposits formation. That is, there are all favorable conditions in the Black Sea for the formation of a stable structure of gas hydrates with a high degree of hydrate saturation.

The accumulation of gas hydrate does not occur in free space – in sea water, but in the massif of the sea bed rocks, which indicates the heterogeneous structure of gas hydrate deposits and the neccesity to take this feature into account when calculating the amount of thermal energy for the dissociation of gas hydrate deposit. There are two variants of hydrate accumulation – at contacts of the rock particles, which leads to cementation of the sedimentary deposits skeleton, and the formation of gas hydrates in the cavities and pores.

It has been established that gas hydrate accumulations in mine rocks exist in the form of the following cryohydrate structures: massive (in sandy soils); porphyry (in sandy-loam soils); lenticular-schlieren (in clay soils). The gas hydrates may be a cement or simply fill in the voids without cementing the sediment grains. The sedimentary rocks strengthening occurs due to the presence of hydrates in them, which perform the role of cement. Also, the gas hydrates can exist in the pore space, without having a noticeable influence on the stiffness and strength of sedimentary rocks. The gas hydrates formation in the seas in the conditions of bottom rocks suggests the filling of the existing voids not with water, but with a solid gas hydrate skeleton.

It was determined that under the conditions of the Black Sea basin, the gas hydrate deposits dominate of not pure, but of heterogeneous structure, that is, comprising a certain proportion of aluminosilicate inclusions. A new classification of gas hydrate deposits with a heterogeneous structure and with a different proportion of rock inclusions in gas hydrate has been developed, the classification feature of which is the amount of heat spent on the dissociation process.

It is recommended to focus on the thermal treatment method when developing the gas hydrate deposits. Its application is characterized by minimal impact on the Black Sea ecosystems. Due to the water intake from the upper homogeneous sea layers for decomposition of gas hydrate deposits (with a temperature not lower than +8ºC, beginning with the depths of 100 m, and in summer period the average temperature of the seasonal thermocline fluctuates at the level of +20ºC), the heat spent for heating is significantly reduced, which is an additional advantage.

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resources"; GP-501 "Identification of patterns of phase transformations of gas hydrates and the stress-strain state of the rock massif, as well as development of the innovation geotechnologies".

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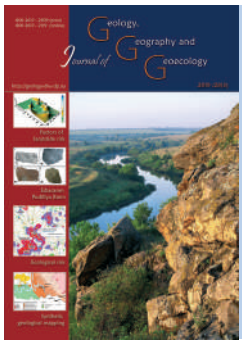

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Dynamics of migration property of some heavy metals in soils in Kharkiv region under the influence of the pyrogenic factor

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Abstract. In soils after fires trace metals sharply change their migration ability and can form poorly-soluble hydroxides which are hazardous chemical formations, the nature of which has not been fully explored until now. In addition, in interstitial water, there is a probability of the formation by metals of hydroxocomplexes with different amounts of hydroxide ions. We studied the range of dynamics of migration capacity of sedimentation of hydroxides and the region of predominance of soluble hydroxocomplexes by developing logarithmic concentration diagrams (LCD). We developed logarithmic concentration diagrams, the equation of formation of prevailing forms, using which it is possible to clearly determine the regions of maximum sedimentation (accumulation) of hydroxides and hydroxocomplexes of heavy metals after the influence of the pyrogenic factor. The obtained calculations of the results of the predictive modeling of the dynamics of migration capacity and postpyrogenic migration geochemical processes in ecogeosystems have been organized and systematized. The determined patterns can be useful for the analysis of possible geochemical migration (accumulation) of heavy metals in ecological systems in the study of technogenic and ecological situation after fires. Based on the calculations made, mathematical models of heavy metals` behaviour are developed, which are useful for drawing up a forecast estimation of the dynamics of their geochemical migration and accumulation in ecological systems as a result of the influence of the technogenic loading of the pyrogenic factor. The conditions of concentration and migration of compounds of heavy metals were determined, and the equation for calculating the concentration of mobile forms of trace metal compounds has been developed. The developed map of the activity of geochemical migration of heavy metals under the influence of the technogenic loading of pyrogenic factor will make it possible to elaborate the migratory capacity of trace metals and provide a forecast of their behaviour in ecological systems after fires. This will allow preventive measures to be taken to ensure environmental safety and prevent adverse effects on human health and the condition of the components of the environment. The creation of similar cartographic material may be extrapolated to other regions of Ukraine, affected by technogenic loading of pyrogenic factor. The development of logarithmic concentration diagrams allows us to predict the capacity of compounds of lead, nickel, chromium,and copper for migration or accumulation of heavy metals due to changes in the acidity of soils under the influence of the pyrogenic factor. Having used the map of the soils of the Kharkiv region, we analyzed and provided a forecast of the migration ability of lead compounds in cases of fire in different types and subtypes of different environmental conditions.

Key words: natural fires, heavy metals, migratory properties of chemical element, map of soils.

Динаміка міграційної здатності деяких важких металів у ґрунтах Харківського регіону під дією пірогенного чинника

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Анотація. У ґрунтах після пожеж важкі метали різко змінюють свою міграційну здатність і можуть утворювати важкорозчинні гідроксиди, які є небезпечними хімічними утвореннями, природа яких до цього часу повністю не досліджена. Крім того, у ґрунтовому розчині є ймовірність утворення металами гідроксокомплексів з різною кількістю гідроксид-іонів. Діапазон динаміки міграційної здатності осадження гідроксидів і області переважання розчинних гідроксокомплексів вивчені нами за допомогою побудови концентраційно-логарифмічних діаграм (КЛД). Побудовано концентраційно-логарифмічні діаграми, виведено рівняння утворення переважаючих форм за допомогою чого можна чітко визначити області максимального осадження (акумуляції) гідроксидів та гідроксокомплексів важких металів після впливу пірогенного чинника. Отримані розрахунки результатів прогностичного моделювання динаміки міграційної здатності та постпірогенних міграційних геохімічних процесів в екогеосистемах нами були упорядковано та систематизовано. Виведені закономірності можуть бути корисними для аналізу можливої геохімічної міграції (акумуляції) важких металів в екогеосистемах при вивченні техногенно-екологічної ситуації після пожеж. На підставі проведених розрахунків розроблено математичні моделі поведінки важких металів, які корисні для складання прогнозної оцінки динаміки їх геохімічної міграції та акумуляції в екогеосистемах в результаті впливу техногенного навантаження пірогенного походження. Встановлено умови концентрування і міграції сполук важких металів, виведено рівняння для розрахунку концентрації рухомих форм сполук важких металів. Побудована карта активності геохімічної міграції важких металів під впливом техногенного навантаження пірогенного походження дозволить деталізувати міграційну здатність важких металів та надати прогноз їх поведінки в екогеосистемах після пожеж. Це дозволить вжити превентивних заходів щодо забезпечення екологічної безпеки та негативного впливу на здоров'я людини та стан компонентів навколишнього природного середовища. Створений подібний картографічний матеріал можливо екстраполювати на інші регіони України, що зазнають техногенного навантаження пірогенного походження. Побудова концентраційно-логарифмічних діаграм дозволяє прогнозувати здатність сполук плюмбуму, нікелю, хрому, купруму до міграції або акумуляції важких металів унаслідок зміни кислотності ґрунтів під дією пірогенного чинника. Використавши карту ґрунтів Харківського регіону, нами проаналізовано та надано прогноз міграційної здатності сполук плюмбуму при виникненні пожежі у різних типах та підтипах різних екологічних умов.

Ключові слова: природні пожежі, важкі метали, міграційні властивості хімічних елементів, карта ґрунтів.

Introduction. The dynamics of geochemical peculiarities of migration of heavy metals under the influence of the pyrogenic factor has been studied in our previous works (Buts et al., 2018, Buts, Y., Kraynyuk, O. 2018), where we proved that after a fire, acidity of soil increases. No doubt, first of all, this is related to increase in the amount of ash and remains of combustion products which have alkaline reaction (Suchikova Y., et al., 2017). Also, an important role in migration or accumulation of elements belongs to the condition of flammable materials, particularly – moisture of forest litter. Increase in alkalinity to 15% was reported by the authors (Burlakova et al., 2002). This study is a continuation of our study published earlier (Buts, 2018, Asotskyi V., 2018).

The **objective** of this study was analysis of the dynamic of migrational ability of heavy metals in soils of Kharkiv Oblast under the impact of the pyrogenic factor. **For this purpose, we solved the following tasks**: suggesting a mathematical model of behaviour of heavy metals for predictive assessment of their geochemical migration and accumulation in ecogeosystems as a result of impact of technogenic load caused by the pyrogenic factor; determining conditions of concentration and migration of compounds of heavy metals and their dynamic, finding a mathematical description of concentration of mobile forms of compounds of heavy metals.

Materials and methods. Reduction of acidity of the soil column contributes to increase in oxidizing-restorative potential, which reflects in maintaining of exchangeable Ca^{2+} and Mg^{2+}. Change in soil pH also affects the migration property of heavy metals.

As we know, different plants differently accumulate various microelements, including heavy metals. That is, one should take into account also the pattern of distribution of heavy metals in the above-ground organs of plants. This pattern is related to various parameters of dynamics of geochemical migration of chemical elements during and after fire .The most characteristic parameter is radial distribution of most heavy metals (HM) in soil section, including the upper soil horizons with interlayers of fragments of plant litter and forest litter. In this case, HM concentration in radial differentiation in the soil column significantly fluctuates, which is well described in scientific publications (Neshovorova, 2014).

Obviously, heavy metals in soils can form poorly-soluble hydroxides. Furthermore, in soil sections, there is a possibility of metals to form hydroxocomplexes with different amounts of hydroxide-ions. We studied the range of sedimentation of hydroxides and the area of predominance of soluble hydroxocomplexes by developing logarithmic concentration diagrams (LCD) (Buts, 2018).

The obtained calculations can be used for predicting dynamics of geochemical migration of heavy metals in soils after technogenic consequences of disasters caused by pyrogenic factors.

Using such calculations, we have developed a logarithmic concentration diagram, according to which one can clearly designate areas of maximum sedimentation of hydroxides of metals.

Predicted model of migration of compounds of lead in ecogeosystems. We have conducted a study attempting to determine the probability of mathematical regularity and its dynamic in formation of migration of poorly-soluble compounds of heavy metals in soils after technogenic impact caused by the pyrogenic factor. For lead, the following pattern is observed: at pH<7, all lead in the soil will be present in soluble form; at pH=8, concentrations $[Pb^{2+}]$ will equal higher than 0.01 mol/l, i.e. at shift of pH to more alkaline area, solubility of plumbum compounds steeply decreases. At pH=9, concentrations $[Pb^{2+}]$ will not exceed 10^{-4} mol/l. At pH=9–13, in the soil environment, particles of $[Pb(OH)^{+}]$, $Pb(OH)_2$ and $Pb(OH)_3^-$ will be present, solubility of which is very low, i.e. in low-alkaline and alkaline environment, compounds of lead accumulate, and therefore their migration is not possible (Fig. 1).

Developing dependency of concentration of most probable ions $[Pb(OH)_n^{2-n}]$ on pH environment and line of trend (Fig. 1) allows one to make a predictive assessment of migration or accumulation of compounds of lead in the soil column. Dependency of soluble compounds of lead on pH can be described by the following pattern:

$$\lg[Pb(OH)_n^{2-n}] = 0.0109 \cdot pH^3 - 0.0888 \cdot pH_2 - 1.891 \cdot pH + 13.064 \quad (1)$$

Reliability of approximation $R^2=0.99$.

Thus, among all particles $[Pb(OH)_n^{2-n}]$, Pb^{2+} are dominant in acidic and neutral environment. Their concentration in interstitial water is described by the equation (1) which is applicable for pH>6.5. At pH<6.5 all lead in interstitial water will be present in soluble form as Pb^{2+}. At pH=9–13, non-soluble particles $[Pb(OH)_n^{2-n}]$ form, mainly $Pb(OH)_2$, migration of lead compounds does not take place, and its accumulation is observed.

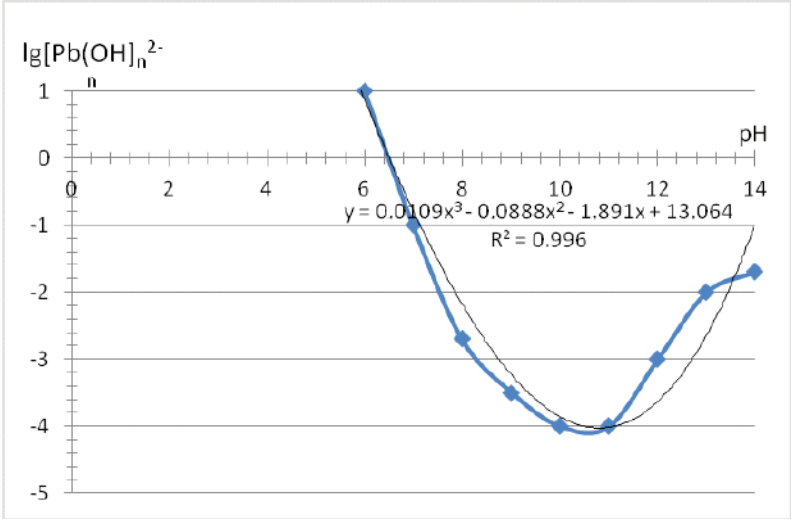

Fig. 1. Dependency of formation of particles $[Pb(OH)_n^{2-n}]$ on pH of soil environment

Predictive model of migration of compounds of chrome in ecogeosystems. In acidic environments, all chrome present in the soil section will be in soluble form (Fig. 2): at pH=4, concentration $[Cr^{3+}]$ can reach 1 mol/l, but at increase in pH to 5, concentration of this chemical element $[Cr^{3+}]$ will equal only 0.01 mol/l; at pH=7–10, non-soluble $Cr(OH)_3$, $Cr(OH)^{2+}$ predominate. In alkaline environments at pH>9, soluble hydroxocomplexes $Cr(OH)_4^-$ begin to form, concentration of which at pH=11 will equal 0.001 mol/l, and at pH=12 increases by 10 times to 0.01 mol/l.

Development of dependency of concentration of most probable ions $[Cr(OH)_n^{3-n}]$ on pH environment and trend line (Fig. 2) allows one to make a predictive assessment of migration or accumulation of chrome compounds in interstitial water. Dependency of soluble compounds of chrome on pH can be described with the following pattern:

$$\lg[Cr(OH)_n^{3-n}] = -0.002 \cdot pH^4 + 0.0599 \cdot pH^3 - 0.4087 \cdot pH^2 - 0.9691 \cdot pH + 6.6899 \quad (2)$$

Reliability of approximation is $R^2=0.99$. Thus, among all particles $[Cr(OH)_n^{3-n}]$, predominating are Cr^{3+} predominate in acidic environments. Their concentration in interstitial water is described by equation (2) applicable for pH>4. At pH<4, all chrome present in soil will be in soluble form as Cr^{3+}. At pH=7–10, non-soluble particles $[Cr(OH)_n^{3-n}]$ form, mainly $Cr(OH)_3$, migration of chrome compounds does not occur, its accumulation is observed, and only in highly alkaline environments will chrome again change to soluble form as negatively charged hydroxocomplexes with a high number of hydroxide ions.

Predictive model of post-pyrogenic geochemical migration of compounds of copper in ecogeosystems. According to the LCD that we developed, one can predict dynamic of mobile forms of compounds of copper depending on pH of environment (Fig. 3). Diagram indicates formation of ions $[Cu(OH)_n^{2-n}]$. In acid environments, Cu^{2+} ions will be present, the quantity of which in

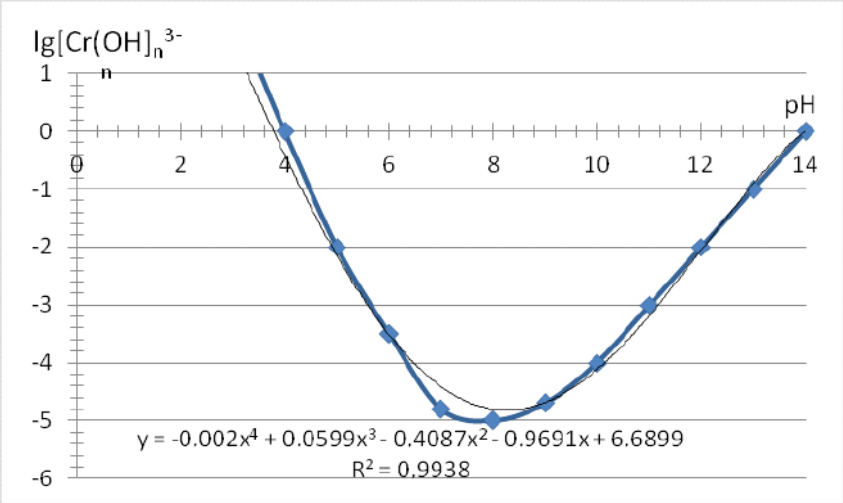

Fig. 2. Dependency of formation of particles $[Cr(OH)_n^{3-n}]$ on pH of soil environment

Thus, dependency of soluble copper compounds on pH can be described as follows:

$$lg[Cu(OH)_n^{2-n}] = 0.0068 \cdot pH^3 - 0.0089 \cdot pH^2 + 2.2185 \cdot pH + 9.251 \quad (3)$$

This dependency correlates well with the developed logarithmic concentration diagram, which indicates reliability of approximation R^2=0.99.

It should be noted that among all particles $[Cu(OH)_n^{2-n}]$, the dominant are Cu^{2+}. Their concentration in interstitial water is described using equation (3), which is applicable at pH=3. At pH<3, all cuprum present in interstitial water is present in insoluble form.

interstitial water will steeply decrease after increase in pH. For example, at pH=4.5, concentration of ions $[Cu^{2+}]$ can reach 1 mol/l; at pH=5, $lg[Cu^{2+}]$= -1, i.e. concentration of ions $[Cu^{2+}]$ will not exceed 0.1 mol/l; and at pH=6, $lg[Cu^{2+}]$=-3, and therefore concentration of ions $[Cu_{2+}]$ will not exceed 0.001 mol/l; further at pH higher than 7, the amount of $[Cu^{2+}]$ becomes insignificant, and non-soluble $Cu(OH)_2$ forms; and only at pH close to 14, do ions of $[Cu(OH)_3^-]$ form in insignificant amount, solubility of which is slightly higher than solubility of $Cu(OH)_2$, but is still low.

For optimizing predicting migration of compounds of copper, we have developed a separate dependence of concentration of most probable ions $[Cu(OH)_n^{2-n}]$ on pH of environment and also developed the trend line. Using the latter, let us demonstrate the tendency in this model and make a probable prediction of the dynamics of their behaviour (Fig. 3).

Predictive model of migration of compounds of nickel in ecogeosystems. In acidic and neutral environments, mobile forms of nickel compounds predominate. At pH<5, all nickel will be present in soluble form as Ni^{2+}; at pH=5, $lg[Ni^{2+}]$=0, i.e. concentration $[Ni^{2+}]$ can reach 1 mol/l; at shift of pH to 5.5, concentration $[Ni^{2+}]$ will not be higher than 0.1 mol/l; and at pH=6, amount of $[Ni^{2+}]$ will not exceed 0.01 mol/l (Fig. 4). At pH>8, compounds of nickel will be present in non-soluble form.

For predictive assessment on dynamics of migration or accumulation of nickel compounds in interstitial water, we have specifically developed a dependency of concentration of most probable ions

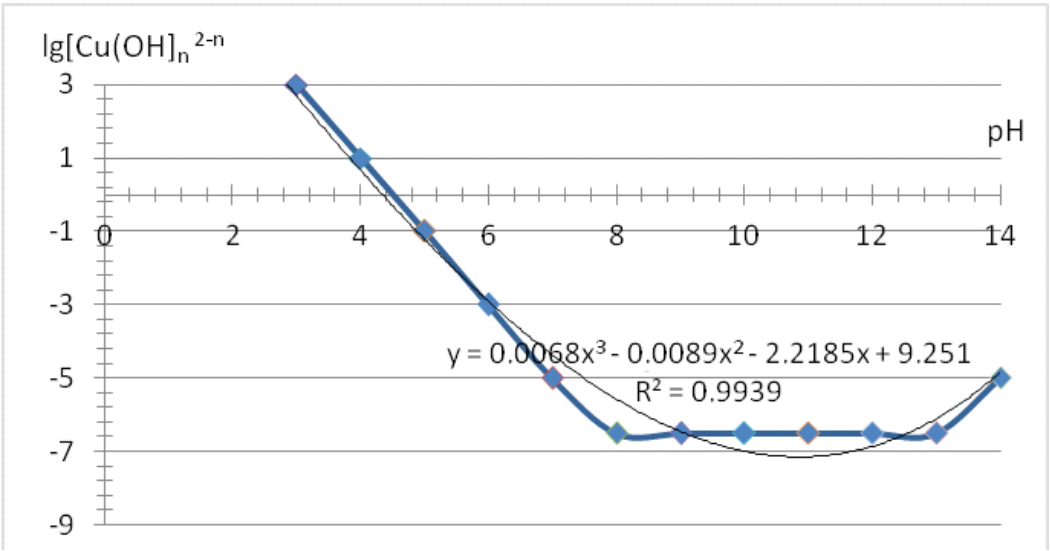

Fig. 3. Dependency of particles $[Cu(OH)_n^{2-n}]$ on pH on soil environment

$[Ni(OH)_n^{2-n}]$ on pH of environment and developed a trend line (Fig. 4). Dependency of soluble compounds of nickel on pH can be described as follows:

$$lg[Ni(OH)_n^{2-n}] = 0.0147 \cdot pH^3 - 0.1968 \cdot pH^2 - 1.1505 \cdot pH + 8.5013 \quad (4)$$

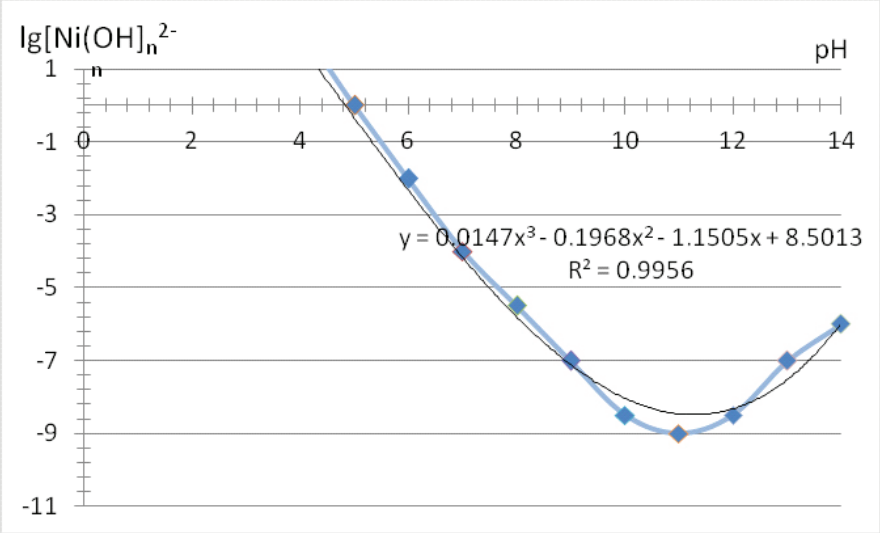

Fig. 4. Dependency of formation of particles $[Ni(OH)_n^{2-n}]$ on pH of soil environment

This dependency correlates well with the developed logarithmic concentration diagram, which is indicated by reliability of approximation $R^2=0.99$.

Thus, amid all particles $[Ni(OH)_n^{2-n}]$, Ni^{2+} predominate in acidic and neutral environments. Their concentration in interstitial water is described by equation (4) which is applicable for pH>5. At pH<5, all nickel in interstitial water will be present in soluble form as Ni^{2+}. At pH=8–14, non-soluble particles $[Ni(OH)_n^{2-n}]$ form, mainly $Ni(OH)_2$, migration of compounds of nickel is almost impossible. Nickel concentrates.

We have systematized calculations of the results of predictive modeling of post-pyrogenic migrational geochemical processes in ecogeosystems (Table 1), therefore they can be useful for analysis of probable dynamic of geochemical migration (accumulation) of heavy metals in ecogeosystems in the study of technogenic-ecological situations after fires.

Results and their analysis. Predicted activity of dynamics of geochemical migration of heavy metals in ecogeosystems under the influence of technogenic load caused by pyrogenic factors (on the example of Kharkiv region). Let us consider, on the example of Kharkiv region, map of soils, obtained using interactive map of soils of Ukraine (Interactive map of soils of Ukraine), comparing which with an atlas of soils (Krupskij, 1979) allowed us to thoroughly study properties of soil in the region, including their acidity. Parameter of pH of soils in Kharkiv region ranges from 4.5 to 9.6 (Table 2).

Table 1. Table of results of predictive modeling of post-pyrogenic migratory geochemical processes in ecogeosystems

Me	Equation of dependency of concentration of soluble forms of metals on pH of soil environment	Conditions of using equation	Note. Conditions of migration or accumulation of heavy metals
Cu	$lg[Cu(OH)_n^{2-n}]=0.007 \cdot pH^3 - 0.009 \cdot pH^2 + +2.22 \cdot pH + 9.25$	pH >3	At pH<3, all cuprum in soluble form Cu^{2+} At pH=7-14, all copper accumulates in soil in non-soluble form
Ni	$lg[Ni(OH)_n^{2-n}]= 0.015 \cdot pH^3 - 0.20 \cdot pH^2 - - 1.15 \cdot pH + 8.50$	pH>5	At pH<5, nickel is in soluble form Ni^{2+}. At pH=8–14, nickel accumulates in soil
Pb	$lg[Pb(OH)_n^{2-n}]= 0.011 \cdot pH^3 - 0.089 \cdot pH^2 - -1.89 \cdot pH + 13.06$	pH>6,5	At pH<6.5, lead is in soluble form Pb^{2+}. At pH=9–13, all lead accumulates in soil
Cr	$lg[Cr(OH)_n^{3-n}]= -0.002 \cdot pH^4 +0.06 \cdot pH^3 - -0.41 \cdot pH^2 - 0.97 \cdot pH + 6.69$	pH>4	At pH<4, all chrome is in soluble form Cr^{3+}. At pH=7–10, it accumulates

Table 1. Soil acidity of Kharkiv region

Soil	pH	Soil	pH
Sod-podzolized soils	4.6-5.7	Chernozems on common loess rocks	
Podzolized soils:		Average humus	6.9-7.2
Grey	4.5-5.1	Low-humus	7.2-7.3
Dark-grey	6.8-7.0	Deposit-solonetzic chernozem soils on loess rocks	6.9-7.6
Podzolized chernozems	7.0-7.1	Meadow-chernozem soils	9.5-9.6
Regradated soils	7.2	Meadow soils	9.5-9.6
Deep chernozems on loess rocks	6.7-6.8	Sod soils	5.7–6.7

For meadow-chernozem and meadow soils, characterized by pH>9, migrational property of most HM after effect of a pyrogenic factor will not change in any way(Fig. 5). There is observed accumulation of HM compounds in soil.

Most likely, in soils of podzolized dark-grey, podzolized chernozems (with pH close to neutral), there will be observed formation of soluble compounds of HM, which will lead to activation of migration in soil, or introduction or accumulation of them in plants. As a result of fire, pH can increase up to 7.5-7.8, which indicates decrease in solubility of HM compounds and their accumulation in soil. These soils are mostly located in Zhovtneve forestry.

A similar situation is characteristic of regradated chernozems (Fig. 5) located in the north and north-east of Kharkiv Oblast (Hutiansky, Kupiansky, Zhovtnevy forestries).

Such prediction can be made also for common chernozems on loess parent rocks which dominate in the northern part of Kharkiv Oblast (Balakliisky, Krasnohradsky, Iziumsky, Blyzniukivsky forestries).

Most likely, for soils of podzolized dark grry chernozems (with pH close to neutral), formation of soluble compounds of lead will be observed, leading to its migration in soil and introduction and accumulation in plants. After fire, pH can increase up to 7.5-7.8, causing reduction in solubility of compounds of lead and their accumulation in soil. These soils are mostly located in Zhovtneve forestry.

Conclusions. According to the conducted assessments, we have developed mathematical models of dynamic of behaviour of heavy metals, useful for making predictive assessments of their geochemical migration and accumulation in ecogeosystems as a result of impact of technogenic load caused by the pyrogenic factor. We determined conditions of concentration and migration of compounds of heavy metals, and formulated an equation for calculation of mobile forms of heavy metal compounds (Table 1).

The mathematical models were developed on the basis of logarithmic concentration diagrams which take into account formations of equal-weight concentrations of different compounds of heavy metals in conditions of technogenic load caused by the pyrogenic factor.

The developed interactive map of activity of geochemical migration of heavy metals under the impact of technogenic load caused by pyrogenic factors will help provide more details for the assessment of migrational properties of HM and prediction of the dynamic of their behaviour in ecogeosystems after fires. Similar cartographic material can be extrapolated for other regions of Ukraine, which are affected by technogenic pyrogenic load.

Development of logarithmic concentration diagrams allows prediction of the property of compounds of lead to migrate or accumulate as a result of acidity of soils under the impact of the pyrogenic factor. We analyzed the map of soils in Kharkiv region and made a prediction of the migrational property of heavy metals in the event of fire in different forestries.

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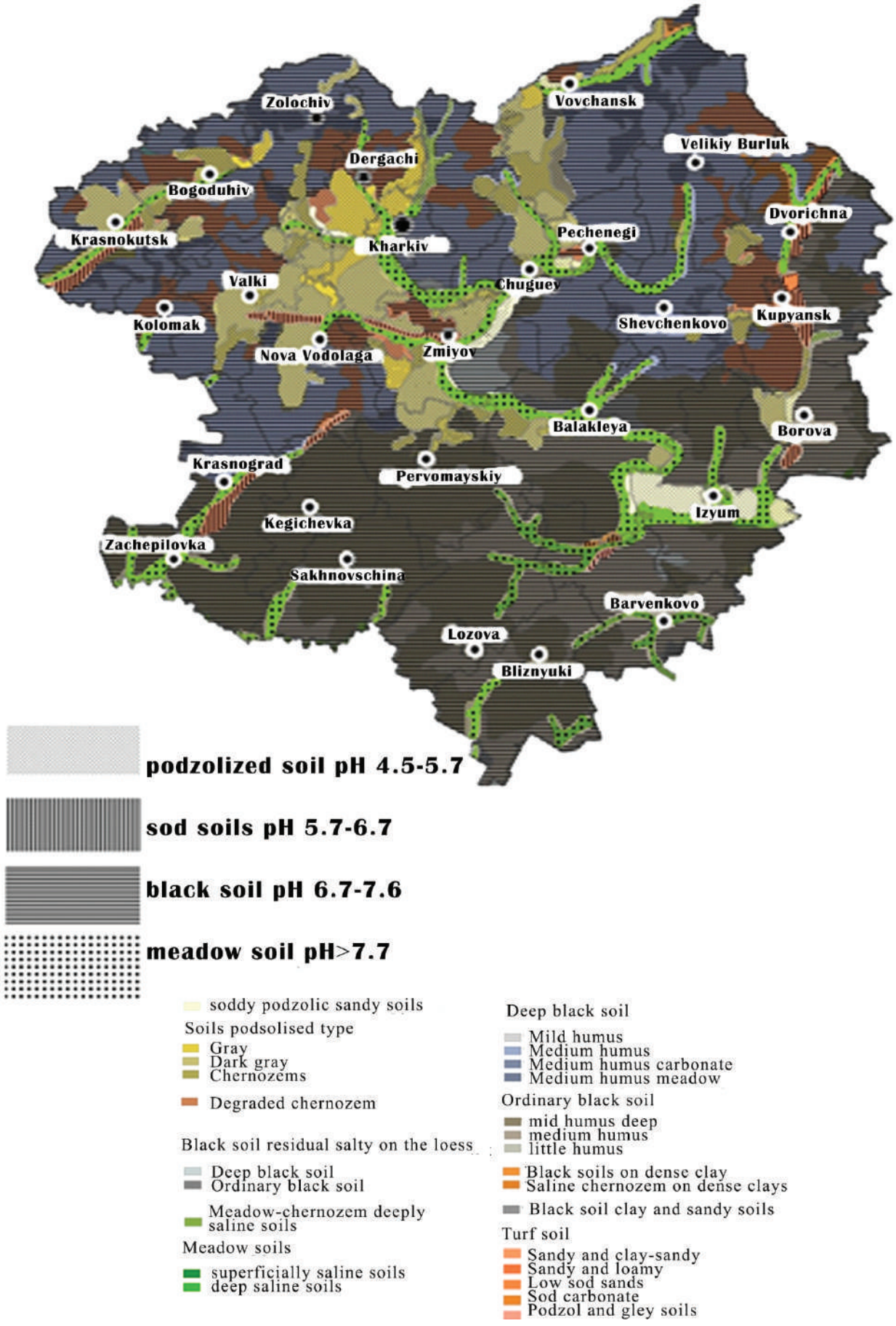

Fig. 5. Activity of geochemical migration of heavy metals under the influence of technogenic load caused by the pyrogenic factor (on example of Kharkiv region)

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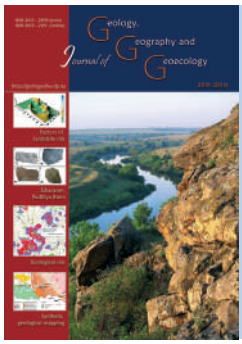

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The catena aspect of the landscape diversity of the «Dnipro-Orilsky» natural reserve

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Abstract. In the present investigation catena approaches to assess the landscape diversity of the "Dnipro-Orilsky" natural reserve was developed. Catena which lies in the reserve embraces flood and arena biogeocoenoses. The research was performed during the 2014–2018. The two profiles were made at the "Dnipro-Orilsky" natural reserve within which main geomorphological landscape elements are presented. There are 29 sampling polygons within these p rofiles. The soil profile description, vegetation investigation, soil and soil animals quantitative assessment was carried out in each of them. In this publication we presented the results of sampling polygons 1–4, 25 and 26. The profile 1 best reflects the traditional view of catena: it goes from the highest places of the sand terrace (arena) to the lowest place (floodplain). But relief diversity is increased by the availability of small river Protich. It floodplain provides an alternative transit and accumulation gradient. It should be noted that the main part of the main slope profile does not fully meet the transit regime, as compiled by sandy soils, which are characterized by high filtration capacity. Therefore, the slope profile position is largely corresponded to eluvial regimes. The accumulative part of the profile which corresponds to the floodplain of Dnipro river is significantly influenced by impact of the flood factor than the accumulative part of the profile which corresponds to the floodplain of Protich river. The soils within floodplain of Protich river have more quantity of clay. Clay soils are characterized by capillary properties, as soil salinization is common in the floodplain of Protich river. Alternative profile 2 includes Orlov valley. This element of the landscape is accumulative, but not affected by flood factor. In the biogeocenotic context catena sampling points were considered as being composed of pedocatena, phytocatena and zoocatena. The biogeocenotic approach is the chain that connects the landscape structure, the diversity of soil cover, and diversities of the plant and animal communities. The functional, spatial and temporal properties of ecosystems in landscape context can be expressed by catena. The biogeocoenosis concept is a basis for integration of the pedocatena, phytocatena and zoocatena. Catena approach is the framework for a monitoring system landscape diversity both at the level of individual component biogeocoenosis (edaphotop, phytocenosis, and zoocenosis) and biogeocoenosis level in terms of its horizontal and vertical structure and at the landscape level as a whole interconnected system. The traditional idea of catena as a set of eluvial, transit and accumulative positions in a complex and diverse landscape is not able to cover the most important environmental gradients modes. The complexity of the landscape is due to relief diversity and the effects of anthropogenic transformation biogeocenotic cover. Catena therefore can be seen as a multilevel hierarchical system of the biogeocenotic polygons needed to consider the diversity of physiographic conditions and anthropogenic gradients.

Key words: catena, landscape, soil, natural reserve, diversity

Катений аспект ландшафтного різноманіття природного заповідника «Дніпровсько-Орільський»

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Анотація. У дослідженні був розроблений катений підхід для оцінки ландшафтного різноманіття природного заповіднику «Дніпровсько-Орільський». Катена, яка знаходиться у заповіднику, охоплює заплавні та арені біогеоценози. Дослідження про-

водилося протягом 2014–2018 рр. У межах природного заповіднику «Дніпровсько-Орільський» закладені два профілі, у межах яких представлені основні геоморфологічні елементи ландшафту. Уздовж профілів розміщені 29 експериментальних полігонів. Описи грунтового профілю, вивчення рослинності, ґрунтів і кількісна оцінка ґрунтових тварин були проведені в кожному з цих полігонів. У цій публікації ми представили результати по полігонам 1–4, 25 і 26. Профіль 1 найкраще відображає традиційне уявлення про катену: він йде з найвищих місць на боровій терасі (арена) до найнижчого місця (заплава р. Дніпро). Але різноманітність рельєфу збільшується за рахунок наявності малої річки Протіч. Її заплава забезпечує альтернативний транзитний і акумулятивний градієнти. Основна частина головного профілю схилу не у повній мірі відповідає транзитного режиму, так як він складений з піщаних ґрунтів, які характеризуються високою фільтруючою здатністю. Таким чином, положення профілю схилу в значній мірі відповідає елювіальний режимам. Акумулятивна частина профілю, яка відповідає заплаві річки Дніпра, в значній мірі залежить від впливу фактора повені, ніж акумулятивна частина профілю, яка відповідає заплаві річки Протіч. Ґрунти у межах заплави річки Протіч мають більший вміст глини. Глинисті ґрунти характеризуються капілярними властивостями, тому і засолення грунту значно більш поширене у заплаві річки Протіч. Альтернативний профіль 2 включає в себе Орлову балку. Цей елемент ландшафту є накопичувальним, але не зазанє впливу фактору повені. У біогеоценотичному контексті катену розглядають як сукупність точок відбору проб, які складаються з педокатени, фітокатени і зоокатени. Біогеоценотичний підхід є ланцюгом, що з'єднує структуру ландшафту, різноманітність ґрунтового покриву і різноманітність рослинних і тваринних угруповань. Функціональні, просторові і часові властивості екосистем в ландшафтному контексті можуть бути виражені за допомогою катени. Біогеоценотична концепція є основою для інтеграції педокатени, фітокатени і зоокатени. Катений підхід є основою для системи моніторингу ландшафтного різноманіття як на рівні окремих компонентів біогеоценозу (едафотоп, фітоценоз та зооценоз), на біогеоценотичному рівні в аспекті його горизонтальної та вертикальної структури та і на ландшафтному рівні у якості цілістної системи взаємопов'язаних частин. Традиційне уявлення про катену як набір елювіальних, транзитних та акумулятивних позицій не може повною мірою відобразити найбільш важливі градієнти екологічних режимів. Складність ландшафту виникає внаслідок різноманіття рельєфу та ефектів антропогенної трансформації біогеоценотичного покриву. Тому катена може розглядатися як багаторівнева ієрархічна система біогеоценотичних полігонів, яка необхідна для характеристики різноманіття фізико-географічних умови і антропогенних градієнтів.

Ключові слова: катена, ландшафт, ґрунт, природний заповідник, різноманіття

Introduction. The diversity of the landscape plays an important role in shaping the diversity and stability of living organisms communities (Zhukov et al., 2015). Catena is the elementary structure unit of the landscape (Bahnov et al., 1988). The term «catena» was originally proposed for soil layer of the biogeocenotic cover and in such a narrow scope is traditionally used to date (Milne, 1935; Urusevskaya, 1990). Within the landscape the series of horology units from the top of the watercourse to the watershed is connected to a number of soil types arrayed along a relief slope. The differences between soil types within catena are related to the difference of altitude and slope affecting on drainage (Milne, 1935; Zaugolnova, 2010). These kinds of catena are called «soil catena» or «pedocatena» (Zaugolnova, 2010). The methodology of the soil catena approach was developed by T. Bashnell (1942), F. Hole (1953), D. Yaalon (1971), A. Gerrard (1984). The catenas are distinguished by the following features: a) according their zone-climatic properties; b) according the composition of the soil components; c) depending on the relief genetic type; d) the main differentiating factors in soil catena – features of lithology, erosion role, hydrological regime, nature of surface water redistribution (Fridland, 1972; Karavaeva, 1982; Urusevskaya, 1990; Kozlovsky, 2003; Gennadiev & Kasimov, 2004).

Catena allows you to fully express the natural spatial and temporal properties of ecosystems that characterize their diversity and dynamics (Diduh, 2008). Appropriate horological units in a vegetation cover are called "phytocatena" (Katenin, 1988; Kholod, 1991; Zaugolnova, 2001). In forest science the similar approach is represented by consideration of the forest community series in different types of soil (Romanovsky, 2002). A. E. Katenin (1988) suggested to use the concept catena only in respect of uniform lithological structures. The idea of monolithic and hetorolithic geocatenas allows to use catena concept for relatively homogeneous and heterogeneous areas (Gennadiev & Kasimov, 2004). Depending on this catenas found may be more simple or more complex in structure. The increasing complexity of the phytocatena structure occurs as more and more streams are taken in consideration as a result of increasing the catchment area (Zaugolnova, 2010). The geographical and geochemical systematic of catenas was designed, which includes such taxonomic units as a group, subgroup, category, type, subtype, family, class, genus and species (Gennadiev & Kasimov, 2004).

The catena approach is most commonly used in practice of the soil animals study (Mordkovich et al., 1985; Zhukov et al., 2016). Catena is a geomorphological profile that runs from the highest place certain territory to the lowest. This profile is graduated in the context of individual factors (humidity, temperature, soil salinity, etc.) or a set of landscape conditions. Therefore, catena is a convenient model of the area through which you can evaluate the environmental preferences of the selected species along the gradient environment (Kaprus, 2011). The approaches were developed for the application of catena method to the study of the diversity of the soil animal communities within arena landscape of the Dnipro valley (within

the "Dnipro-Orylskiy" natural reserve) by means of phytoindication assessment of the basic trends of variability of environmental conditions (Zhukov et al., 2016).

From a practical point of view, catena may be considered any arbitrarily chosen of the landscape slope or the whole slope, which is a set of habitats with regular changes in environmental conditions, which is due to the relief (Mordkovich et al., 1985). There is no matter inflow (other than precipitation) at the top of a catena and there is no matter outflow at the bottom. The starting element of catena is an eluvial topographic position, and the terminal is an accumulative topographic position. Among them are transit positions. Standard catena consists from five positions: eluvial, 1st, 2nd, and 3rd transit and accumulative. The soil is responsive to changes in topography. The increase down the slope total wetting of soils and their quality determines the change in plant and animal communities (Mazey & Embulaeva, 2015).

Catena elements can be combined into complexes of a higher hierarchical level. The some links in the chain (catena) which are presented by specific habitats or plant communities, combined in mesocombinations and the last – in macrocombinations. The mesocombinations are also interpreted as ecomeres and can be characterized using phytoindication approach (Didukh et al., 2015).

Diversity is the basis of functional stability of the biogeocenosis (Zhukov & Gubanova, 2015). Soils represent an important aspect of biological diversity and form the aim and conditions of its preservation. Therefore, the study of soil diversity of the «Dnipro-Orilsky» natural reserve is an important and urgent problem. Of particular importance is the study of arena and floodplain soils, characterized by a large diversity of their soil forming process complexity. The variation of the physical properties of the soil has a significant ecological value (Karpachevsky, 2005). The existence of the soil ecomorphes was proved based on the research of spatial-temporal dynamics of soil mechanical impedance (Zhukov & Zadorozhnaya, 2016). Other soil physical properties such as electrical conductivity, density, and wetness are also important genetic and ecological properties (Karpachevskij, 2005; Zhukov et al., 2011; 2012; Zhukov et al., 2016).

The aim of the present investigation is to develop catena approaches to assess the landscape diversity of the «Dnipro-Orilsky» natural reserve.

Materials and methods. Relief of the «Dnipro-Orilsky» nature reserve is presented by the forms of the alluvial or aeolian origin of the Dnipro lowland. There are three terraces within the area of the natural reserve. The well-developed floodplain terrace has the lowest position which is rugged in different directions by numerous channels, dotted with lakes and marshes, stretching along the Dnipro by a belt 16 km. In the widest part, Taromske ledge, floodplain terrace is 2 km and in the narrowest part in the Nicholas ledge is 1 km. The floodplain soils are represented by a layered modern alluvium. Its lower layers are fluvial facies, formed when water levels decline due to settling of sediment deformation during routine bed. The floodplain is covered with numerous lakes, some of which turned into swamps, and rugged by a chain of the winding or sickle oxbow lakes and channels (Manyuk, 2005).

Catena which lies in the reserve embraces flood and arena biogeocoenoses (Fig. 1). The research was performed during the 2014–2018. 29 sampling polygons were made. The soil profile description, vegetation investigation, soil and soil animals quantitative assessment was carried out in each of them. In this publication we presented the results of sampling polygons 1-4, 25 and 26.

The electrical conductivity of the soil was measured in every 5 cm from the soil surface with 3 times frequency. Measuring the electrical conductivity of the soil (apparent soil electrical conductivity – EC_a) ws made by using sensor HI 76305 (Hanna Instruments, Woodsocket, RI) showed a significant performance in conducting soil and environmental studies (Pennisi, van Iersel, 2002; Scoggins, van Iersel, 2006; Smagin, 2012; Zhukov et al., 2011; 2012; Zhukov et al., 2016).

The measurements of soil mechanical impedance were made in the field using hand penetrometer Eijkelkamp with an interval of 5 cm (Zhukov, 2015). The average error of the results of the measurement device is ± 8%. Measurements were performed by the cone with the size of cross section of 2 cm^2. The measurements of soil mechanical impedance were made with 3 times frequency within each soil profile. The bulk density of the soil was determined using the method of Kaczynski, and humidity was determined by weight method (Vadunina, Korchagina, 1986; Zhukov et al., 2015). Morphological Soil profile description was performed according to Rozanov (2004). The expert method was used for the type profiles formalized description of the derived empirical data. Graphical display of the soil profiles completed in the program of Strater © v. 4 (Golden Software, LLC).

Results and discussion. The two profiles were made at the «Dnipro-Orilsky» natural reserve within which main geomorphological landscape elements are presented (Fig. 1). The profile 1 best reflects the traditional view of catena: it goes from the highest places

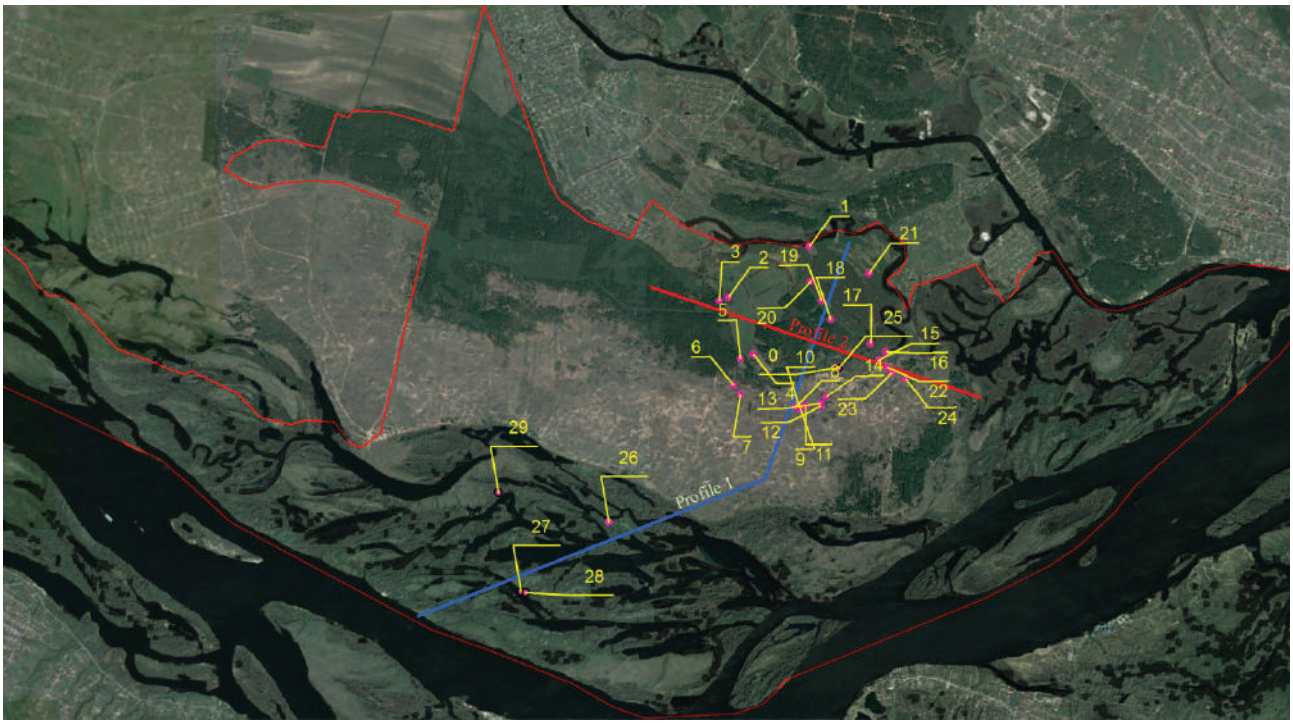

Fig. 1. The placing of biogeocenotic plots within the "Dnipro-Orilsky" natural reserve: sandy terrace: 1 – meadow, floodplain of Protich river; 2 – oak forest, Orlov valley; 3 – artificial pine plantations, the slope of northern exposure of the Orlov valley; 4 – meadow, Orlov valley; 5 – artificial pine plantations, sand hill top; 6 – psamophytic steppe, dune gate (interdune bottom); 7 – psamophytic steppe, the top of the hill; 8 – psamophytic steppe, the top of the hill; 9 – psamophytic steppe, dune gate; 10 – Tatarian maple bush, hillside; 11 – Tatarian maple bush, dune gate; 12 – Tatarian maple bush, hillside; 13 – psamophytic steppe, the top of the hill; 14 – psamophytic steppe, dune gate; 15 – oak forest, floodplain of Protich river; 16 – wooded bog, floodplain of Protich river; 17 – shrub bog, floodplain of Protich river; 18 – artificial pine plantations, slope arena which is adjacent to the floodplain of Protich river; 19 – oak forest, the slope of the arena, which is adjacent to the floodplain of Protich river; 20 – swamp, dune gate; 21 – meadow, floodplain of Protich river; 22 – psamophytic steppe, the top of the hill; 23 – psamophytic steppe, dune gate; 24 – Tatarian maple bush, the top of the hill; 25 – white poplar forest, the floodplain of Protich river. The floodplain of Dnipro river: 26 – oak forest, terrace near flood plain; 27 – oak forest, riverine floodplain; 28 – oak forest, riverine floodplain, Graduation to the central floodplain; 29 – oak forest, central floodplain (image taken from the satellite DG, source – maps.ovi.com)

of the sand terrace (arena) to the lowest place (floodplain). But relief diversity is increased by the availability of small rivers Protich (Table. 1). It floodplain provides an alternative transit and accumulation gradient. It should be noted that the main part of the main slope profile does not fully meet the transit regime, as compiled by sandy soils, which are characterized by high filtration capacity. Therefore, the slope profile position is largely corresponded to eluvial regimes.

The accumulative part of the profile which corresponds to the floodplain of Dnipro river is significantly influenced by impact of the flood factor than the accumulative part of the profile which corresponds to the floodplain of Protich river. The soils within floodplain of Protich river have more quantity of clay. Clay soils are characterized by capillary properties, as soil salinization is common in the floodplain of Protich river.

Alternative profile 2 includes Orlov valley. This element of the landscape is accumulative, but not affected by flood factor.

In the biogeocenotic context catena sampling points were considered as being composed of pedocatena, phytocatena and zoocatena. The most common characteristic biogeocenosis within catena investigated are presented further.

Sampling polygon № 1. The vegetation of meadow included a total of 29 species of vascular plants, among which are dominated by *Poa pratensis* (L), *Calamagrostis epigeios* (L) Roth. *Inula britannica* (L) is a subdominant. The total projective cover of herbaceous species is 100% (Gudym & Ganzha, 2016). For identification of plant communities, within which research was undertaken, we give it a syntaxonomy characteristic.

Syntaxonomy of the plant community:

Class Molinio-Arrhenatheretea Tx., 1937

Ordo *Agrostietalia stoloniferae* Oberd. in Oberd. et al., 1967

Union *Festucion pratensis* Sipajlova et al., 1985

All. *Poetum pratensis* Steppeanović, 1999

The herpetobiont invertebrates community included a total of 80 species representing 28 families

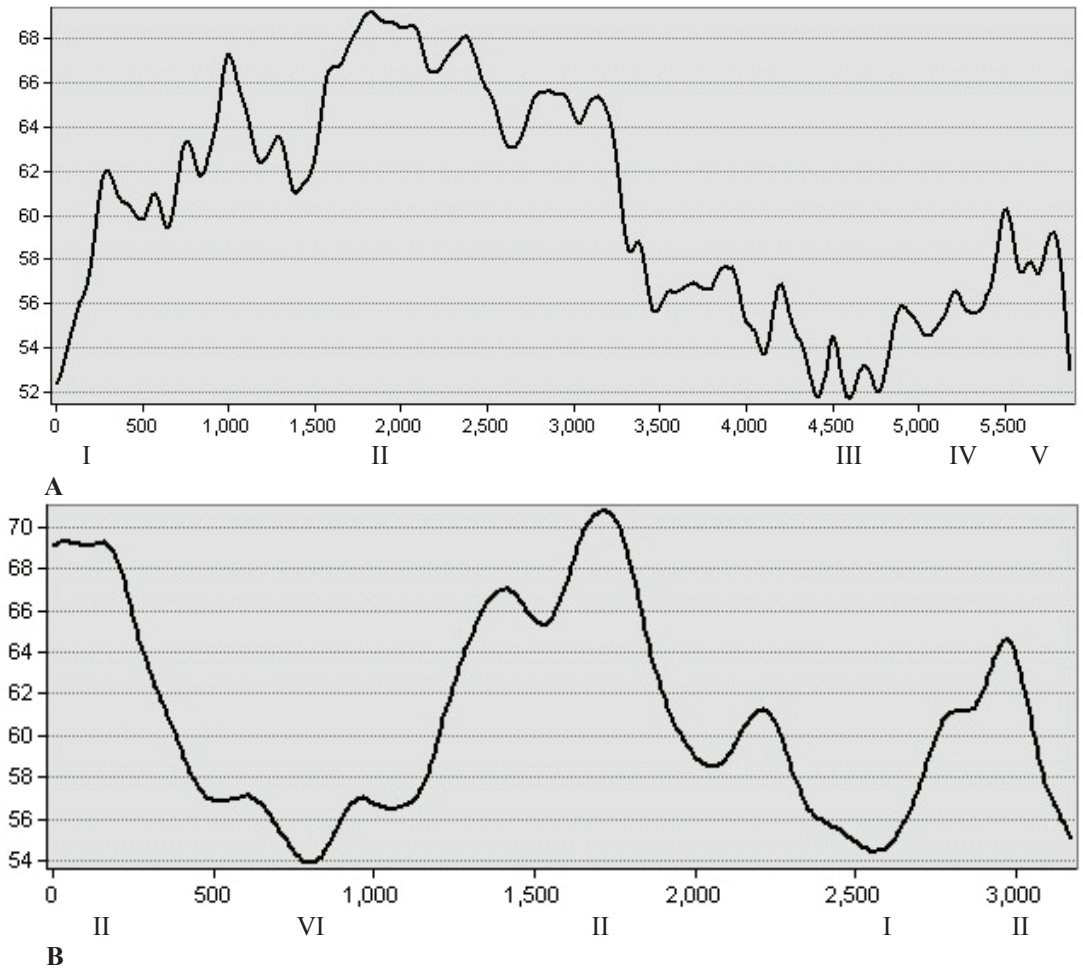

Fig. 2. Geomorphological profiles, along which catena plots are placed: A – geomorphological profile 1, B – geomorphological profile 2: I – floodplain of Protich river; II – sandy terrace; III – terrace near flood plain of Dnipro river; IV – central floodplain of Dnipro river; V - riverine floodplain of Dnipro river; VI – Orlova valley

and 11 orders and 6 classes from two phylum (arthropods and molluscs) at the sampling polygon (Zhukov et al., 2017). *Carabus excellens* and *Taphoxenus gigas* are included in the Red Book of Dnepropetrovsk region (Sumarokov et al., 2018).

Soil profile description

The description was made in 3 October 2018. The soil section was located in the beach of the Protich river within the "Dnipro-Orylskiy" natural reserve (Fig. 3, A). The vegetation is presented by meadow. The soil surface is relatively smooth. There is a litter cover with depth of 3-4 cm and with projective cover 90–100%. The parent material is alluvial sand. The groundwater level is at a depth of 200 cm. There are no the visible soil neoformation, carbonate debris, accumulation of salts. The soil consistency is dense. The genetic type of the profile is humus-gley. An intense carbonate effervescence after dilute hydrochloric acid treatment was occurred from 31 to 90 cm.

H_0 (2–0 cm) – organogenic horizon, litter with projected cover 70–90%.

H_d (0–7 cm) – the upper humus-accumulative soddy horizon. The quantity of roots is common. Dark grey. Moderately moist. Light loam. Loose. Structureless, rare aggregates are unstable, some aggregates are bonded by clusters of grasses roots. Cracks are missing. The distinctness with next horizon is abrupt, may be detected on the basis of the clear roots content decrease and changes of the consistency.

Hk (7–48 cm) – upper humus-accumulative carbonate. Dark grey. Dense. Moist. Light loam. Roots are absent. Cracks are missing. The distinctness with next horizon is gradual, may be detected on the basis of the color.

HPk (48–75 cm) – transition carbonate. Light grey, gradually brightens with depth. Dense. Moist. Light loam. Roots are absent. The distinctness with next horizon is gradual, may be detected on the basis of the color.

Ph1k (75–113 cm) – the first lower transition carbonate horizon. Light gray. Moderately moist. Consistence is compact. Light loam, there are no cracks. Humus spots of irregular shape with a diameter of 15–20 cm are presented. The distinctness with next horizon is gradual, may be detected on the basis of the color.

Ph2 (113–136 см) – the second lower transition. Gray with humus spots. Consistence is compact. Light loam. Moderately moist. The distinctness with next horizon is clear, may be detected on the basis of the color.

Ph3gl (136–152 cm) – the third lower transition gleyey. Blue-gray. Clay sand. There are no cracks. Very moist. Consistence is compact. The distinctness with next horizon is clear, may be detected on the basis of the color.

P1G (152–171 cm) – gley parent material. Dark blue-gray clay sand with reddish spots. Consistence is soft. The distinctness with next horizon is gradual, may be detected on the basis of the texture changes.

P2G (171–200 cm) – gley parent material. Dark blue-gray sand with reddish spots. Consistence is soft.

The working definition of soil: sod carbonate gley soil (Calcic Gleysols (Humic)).

Sampling polygon № 2. The vegetation of oak forest included a total of 48 species of vascular plants. The tree stand are dominated by *Quercus robur* L., *Pyrus communis* L.. The shrub layer are dominated

Table 1. Elements of biogeocenotic catena

N	Biogeoceonosis	Element of the catena	Flood regime	Topographic position
Sandy terrace				
1	Meadow	Accumulative	Short term flooding	Floodplain of Protich river
2	Oak forest	Transitional	Without flooding	Orlov valley
3	Artificial pine plantations	Transitional	Without flooding	The slope of northern exposure of the Orlov valley
4	Meadow	Accumulative	Without flooding	Orlov valley
5	Artificial pine plantations	Eluvial	Without flooding	Sand hill top
6	Psamophytic steppepe	Accumulative	Without flooding	Dune gate
7	Psamophytic steppepe	Eluvial	Without flooding	Sand hill top
8	Psamophytic steppepe	Eluvial	Without flooding	Sand hill top
9	Psamophytic steppepe	Accumulative	Without flooding	Dune gate
10	Tatarian maple bush	Transitional	Without flooding	Hillside
11	Tatarian maple bush	Accumulative	Without flooding	Dune gate
12	Tatarian maple bush	Transitional	Without flooding	Hillside
13	Psamophytic steppepe	Eluvial	Without flooding	Sand hill top
14	Psamophytic steppepe	Accumulative	Without flooding	Dune gate
15	Oak forest	Accumulative	Short term flooding	Floodplain of Protich river
16	Wooded bog	Accumulative	Short term flooding	Floodplain of Protich river
17	Shrub bog	Accumulative	Short term flooding	Floodplain of Protich river
18	Artificial pine plantations	Transitional	Without flooding	The slope arena which is adjacent to the floodplain of Protich river
19	Oak forest	Transitional	Without flooding	The slope arena which is adjacent to the floodplain of Protich river
20	Swamp	Accumulative	Without flooding	Dune gate
21	Meadow	Accumulative	Short term flooding	Floodplain of Protich river
22	Psamophytic steppepe	Eluvial	Without flooding	Sand hill top
23	Psamophytic steppepe	Accumulative	Without flooding	Dune gate
24	Tatarian maple bush	Eluvial	Without flooding	Sand hill top
25	White poplar forest	Transitional	Short term flooding	Floodplain of Protich river
The floodplain of Dnipro river				
26	Oak forest	Accumulative	Moderate term flooding	Terrace near flood plain
27	Oak forest	Accumulative	Moderate term flooding	Terrace near flood plain
28	Oak forest	Accumulative	Moderate term flooding	Graduation to the central floodplain
29	Oak forest	Accumulative	Moderate term flooding	Central floodplain

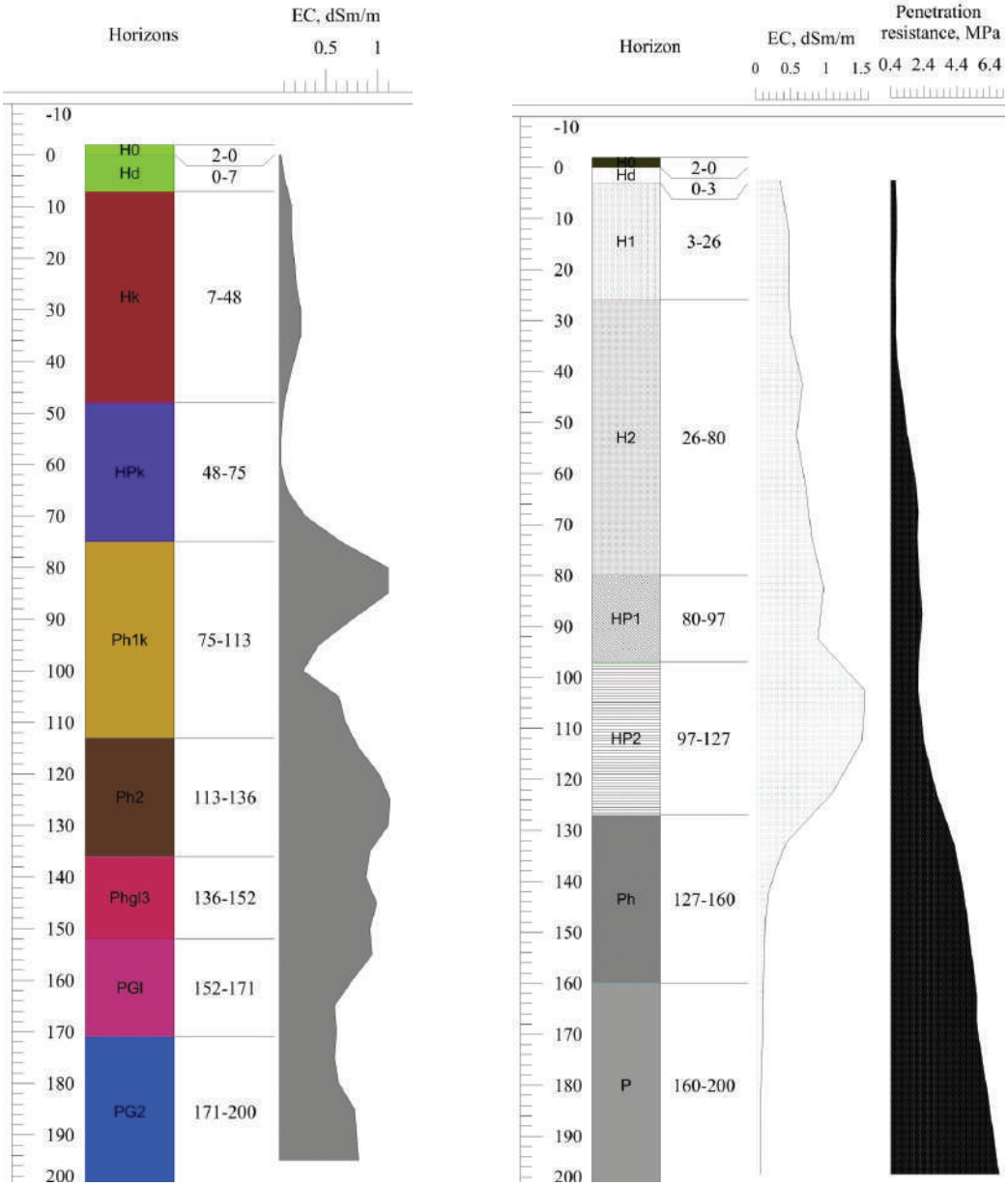

Fig. 3. The profile of sod-gley carbonate soil (Calcic Gleysols (Humic)) (A) and sod-forest chornozem-like deep carbonate soil (Phaeozems Arenic) (B)

***Legend*:** A – H_0 – organogenic horizon, H_d – the upper humus-accumulative soddy horizon, Hk – upper humus-accumulative carbonate horizon, HPk – transition carbonate, Ph1k – the first lower transition carbonate horizon, Ph2 – the second lower transition horizon, Ph3gl – the third lower transition gleyey horizon, P1G – gley parent material, P2G – gley parent material; B – H_0 – organogenic, H_d – upper humus-accumulative, soddy horizon, H_1 – the first humus-accumulative, H_2 – the second humus-accumulative, HP_1 – the fist transition horizon, HP_2 – the second transition horizon, Ph_k – the lower transition carbonate horizon, P_k – parent material.

by *Acer tataricum* L., *Crataegus fallacina* Klokov, *Sambucus nigra* L., the herbaceous layer are dominated by *Galium aparine* L ., *Glechoma hederacea* L., *Urtica dioica* L., *Vincetoxicum rossicum* (Kleop.) Barbar. The total projective cover of herbaceous species is 15–20% (Zhukov et al., 2018). For identification of plant communities, within which research was undertaken, we give it a syntaxonomy characteristic.

Class *Querco-Fagetea* Br.-Bl. et Vlieger in Vlieger 1937
Ordo *Quercetalia pubescenti-petraeae* Klika 1933
Union *Aceri tatarici-Quercion* Zolyomi 1957
All. *Vincetoxico hirundinariae-Quercetum roboris* Sokolova, 2011

The herpetobiont invertebrates community included a total of 66 species representing 24 families

and 11 orders and 7 classes from tree phylum (annelida, arthropods and molluscs) at the sampling polygon (Zhukov et al., 2017). *Carabus excellens* is included in the Red Book of Dnepropetrovsk region (Sumarokov et al., 2018).

Soil profile description

The description was made in 11 September 2017. The soil section was located in the Orlova vallay within the "Dnipro-Orylskiy" natural reserve (Fig. 3, B). The soil surface is relatively smooth. There is the litter consisted from leaves, not decayed, with a depth of 2–3 cm, projective cover is 90–100%. The fallen leaves are disintegrated well, the bottom layer of the litter is dust. The projective cover of the grass layer is 15–20%. The parent material is alluvial sand. The groundwater level was not found. The depth of the roots of trees and shrubs up to 200 cm. There are no the visible soil neoformation, carbonate debris, accumulation of salts. There are some traces of soil invertebrates activity. Evidence of the gleying were not found. Consistence is dense. The genetic profile type is humus differentiated. An intense carbonate effervescence after dilute hydrochloric acid treatment was occurred from 127 cm.

H_0 (2–0 cm) – organogenic, forest litter with projected cover 90–100%.

H_d (0–3 cm) – upper humus-accumulative, soddy. Very dark gray (5Y 3/1). Dry. Clay sand. Consistence is friable. The soil is moderately or weakly bounded by root systems of herbaceous plants. Soil structure is very coarse, grain-dust. There are no ckraks. Animals pedoturbation is occurred. The distinctness with next horizon is abrupt, may be detected on the basis of the color and consistence.

H_1 (3–26 cm) – the first humus-accumulative. Dark gray (7.5YR 4/1). Moderately dry. Clay sand. Dense. There are some roots of shrubs. Structureless. The distinctness with next horizon is abrupt, may be detected on the basis of the color and consistence.

H_2 (26–80 cm) – the second humus-accumulative. Reddish gray (7.5R 5/1), becomes lighter with depth and reddish shade decreases. Slightly moist. Loamy sand. Consistence is compact. Structureless. There are some roots of shrubs. There are fragmentary inclusion of yellow sand grains. The distinctness with next horizon is graduated, may be detected on the basis of the color.

HP_1 (80–97 cm) – the fist transition horizon. There are olive gray (5Y 5/2) or blue gray (5PB 5/1) vertically oriented oval spots 1-2 cm wide and 12.7 cm high on the grey background (2.5Y 6/1). Slightly moist. Consistence is compact. There are no roots. Loamy sand. There are no cracks. Structureless. The distinctness with next horizon is clear, may be detected on the basis of the color.

HP_2 (97–127 cm) – the second transition horizon. Grey-brown background (2.5Y 5/2) with vertical oval dark-gray spots (N 4/0) of the humus material width of 1 cm, height – 3–4 cm. Also, there are some round-spots of irregular shape with a diameter of 7.8 cm, probably – burrows of soil mammals filled by humus material (krotovina). Consistence is compact. Loamy sand. Slightly moist. The distinctness with next horizon is graduated, may be detected on the basis of the color and texture.

Ph_k (127–160 cm) – the lower transition carbonate horizon. Grey (2.5Y 6/1) with dark reddish gray (2.5YR 4/1) spots of the humus material. There are nodules of calcium carbonate on the depth 130–140 cm. Loamy fine sand. Slightly moist. Consistence is compact. The distinctness with next horizon is abrupt, may be detected on the basis of the color and texture.

P_k (160–200 cm) – parent material. Grey-brown (2.5Y 5/2) large-grained sand. Moderately moist, friable. Vertical spots from humus material likely traces of decomposed plant roots width of 1 cm, the height is 15–20 cm, 2–3 spots on 10 cm in the horizontal direction.

The working definition of soil: sod-forest chornozem-like deep carbonate soil (Phaeozems Arenic).

Sampling polygon № 3. The vegetation of artificial pine forest included a total of 31 species of vascular plants. The tree stand are presented by *Pinus sylvestris* L.. The herbaceous layer are dominated by *Calamagrostis epigeios* (L.) Roth., *Elymus repens* (L.) Gould, *Rubus caesius* L.. The total projective cover of herbaceous species is 5–10 % (Gudym and Ganzha, 2016). For identification of plant communities, within which research was undertaken, we give it a syntaxonomy characteristic.

Class Robinietea Jurko ex Hadac et Sofron 1980
Ordo *Chelidonio-Robinietalia* Jurko ex Hadac et Sofron 1980
Union *Balloto nigrae-Robinion* Hadac et Sofron 1980
All. *Calamagrostio epigeioris-Robinietum* Smagaluk 2016

The herpetobiont invertebrates community included a total of 49 species representing 25 families and 12 orders and 7 classes from tree phylum (annelida, arthropods and molluscs) at the sampling polygon (Zhukov et al., 2017). *Taphoxenus gigas* is included in the Red Book of Dnepropetrovsk region and *Carabus (Pachystus) hungaricus* (Fabricius, 1792) is included in the Red Book of Ukraine (Sumarokov et al., 2018).

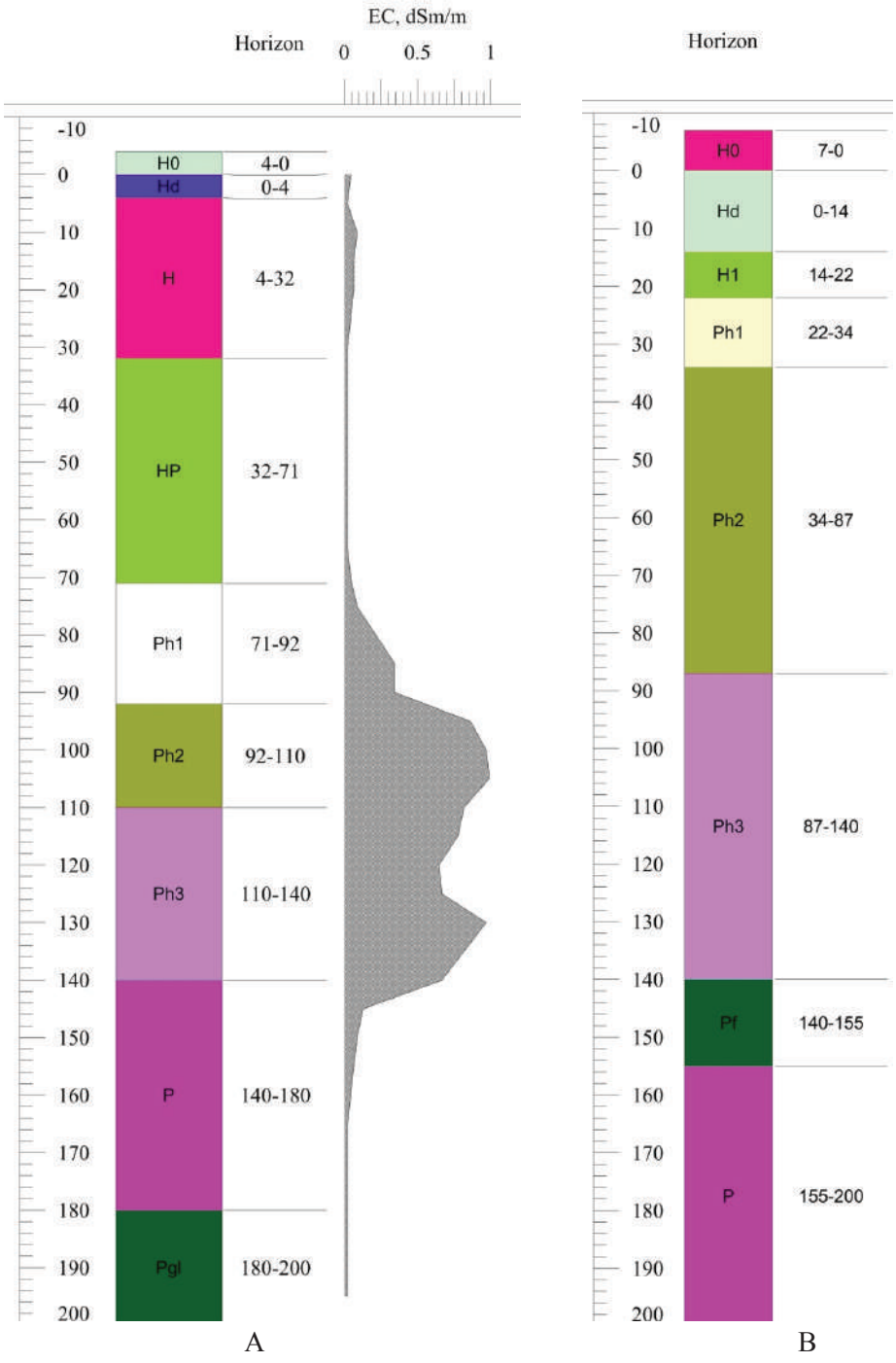

Fig. 4. The profile of sod-pine pseudofibres soil with shot profile (Ferric Arenosol Aridic) (A) and sod gley soil (Gleysols (Humic)) (B)

Legend: A – H_0 – organogenic, H_d – upper soddy humus-accumulative, H_1 – upper humus-accumulative, Ph1 – the first transition, Ph2 – the second transition, Ph3 – the third transition, Pf – pseudofibr horizon, P – parent material; B – H_0 – organogenic horizon, H_d – upper soddy humus-accumulative horizon, H – upper humus-accumulative horizon, HP – transition horizon, Ph1 – the first lower transition horizon, Ph2 – the second lower transition horizon, Ph3 – the third lower transition horizon, P – parent material, Pgl – gley parent material

Soil profile description

The description was made in 24 June 2018. The soil section was located in the artificial pine forest within sand terrace of the Dnipro river (Fig. 4, A). The soil surface is relatively smooth. There is the forest litter consisted from pine needle, not decayed, with a depth of 5–7 cm, projective cover is 100%. The litter has a layered structure, may be easily separated from the surface of the soil. The projective cover of the grass layer is 5–10%. The parent material is alluvial sand. The groundwater level was not found. The depth of the roots of trees and shrubs up to 200 cm. There soil cracks in humus layer but there are no in deeper layers. There are no the visible soil neoformation, carbonate

debris, accumulation of salts. There are some traces of soil invertebrates activity. Evidence of the gleying were not found. Consistence is from loose to dense. The genetic profile type is humus differentiated.

H_0 (7–0 cm) – organogenic, forest litter with projected cover 100%, dry, compressed, well separated from the soil, has a layered structure.

H_d (0–14 cm) – upper soddy humus-accumulative. Brown-gray. Dry. Sandy loam. Layered. Consistence is f loose. Soil is moderately or weakly bounded by root systems of herbaceous plants. Dust-grain structure. The cracks have a mainly horizontal direction. The distinctness with next horizon is abrupt, may be detected on the basis of the color, consistence and root content.

H_1 (14–22 cm) – upper humus-accumulative. Gray. Dry. Sandy loam. It is more dense than the previous horizon, but easily crumbles with a slight clicking. There are roots of herbaceous plants and shrubs. Structureless. The distinctness with next horizon is abrupt, may be detected on the basis of the color and consistence.

Ph1 (22–34 cm) – the first transition. Pale yellow with gray or dark gray spots. The traces of humous residuals of roots in a horizontal direction. Dry. Clay loam. Consistence is dense, almost condensed. There are no roots of living plants. Structureless. The distinctness with next horizon is abrupt and undulate, may be detected on the basis of the color.

Ph2 (34–87 cm) – the second transition. Pale yellow with gray or dark gray spots. The traces of humous large root residuals rounded with diameter 5–7 cm. Dry. Clay loam. Consistence is dense, almost condensed. There are no roots of living plants. Structureless. The distinctness with next horizon is abrupt, may be detected on the basis of the color and consistence.

Ph3 (87–140 cm) – the third transition. Dark yellow with gray or dark gray spots. The traces of humous large root residuals rounded with diameter 5–7 cm. Moderately moist. Sand. Consistence is friable. There are no roots of living plants. Structureless. The distinctness with next horizon is abrupt, may be detected on the basis of the higher margin of the pseudofibres.

Pf (140–155 cm) – pseudofibr horizon. It consists of thin (0.5–0.7 cm) brown compacted layers (pseudofibres) which alternating with layers of yellow sand. Very moist. The distinctness with next horizon is abrupt, may be detected on the basis of the lower margin of the pseudofibres.

P (155–200 cm) – parent material. Light gray sand, very moist. Consistence is friable.

The working definition of soil: sod-pine pseudofibres soil with shot profile (Ferric Arenosol Aridic).

Sampling polygon № 4. The vegetation of meadow included a total of 19 species of vascular plants, among which are dominated by *Calamagrostis epigeios* (L.) Roth., *Cirsium arvense* (L.) Scop., and *Elymus repens* (L.) Gould. The total projective cover of herbaceous species is 90–100 % (Gudym and Ganzha, 2016). For identification of plant communities, within which research was undertaken, we give it a syntaxonomy characteristic.

Syntaxonomy of the plant community:

Class EPILOBIETEA ANGUSTIFOLII R.TX. ET PRSG 1950
Ordo *Epilobietalia angustifolii* R.Tx. 1950
Union *Epilobion angustifolii* R.Tx. 1950
All. *Calamagrostietum epigei* Juraszek 1928

The herpetobiont invertebrates community included a total of 88 species representing 27 families and 10 orders and 6 classes from two phylum (arthropods and molluscs) at the sampling polygon (Zhukov et al., 2017). *Carabus excellens* is included in the Red Book of Dnepropetrovsk region and *Carabus (s.str.) stscheglowi* (Mannerheim, 1827) is included in the Red Book of Ukraine (Sumarokov et al., 2018).

Soil profile description

The description was made in 19 September 2018. The soil section was located in up the Orlova valley within the "Dnipro-Orylskiy" natural reserve (Fig. 4, B). The vegetation is presented by meadow. The soil surface is relatively smooth. There is a litter cover with depth of 3–4 cm and with projective cover 90–100%. The parent material is alluvial sand. The groundwater level is at a depth of 200 cm. There are no the visible soil neoformation, carbonate debris, accumulation of salts. The soil consistency is dense or condence. The genetic type of the profile is humus-gley. There was no an intense carbonate effervescence after dilute hydrochloric acid treatment.

H_0 (4–0 cm) – organogenic horizon, litter with projected cover 70–90%.

H_d (0–4 cm) – upper soddy humus-accumulative horizon. The quantity of roots is common. Dark grey. Dry. Light loam. Loose. The soil is fair aggregated, crumbly. The some aggregate are separately bonded by clusters of grass roots. The aggregate structure is granular-silty. Cracks are missing. The distinctness with next horizon is abrupt, may be detected on the basis of the clear roots content decrease and changes of the color and aggregate structure.

H (4–32 cm) – upper humus-accumulative horizon. Dark grey. Dense. Moist. Light loam. Roots are

absent. Cracks are missing. The distinctness with next horizon is gradual, may be detected on the basis of the color and cracks.

HP (32–71 cm) – transition horizon. Light grey, condensed. Moderately moist. Light loam. The verticals cracks having a width of 0.2 cm create 15–20 cm width pedes. Roots are absent. Roots are absent. Cracks are missing. The distinctness with next horizon is gradual, may be detected on the basis of the color and cracks.

Ph1 (71–92 cm) – the first lower transition horizon. Light gray. Moderately moist. Consistence is compact. Light loam, there are no cracks. Light yellow spots of irregular shape with a diameter of 15–20 cm are presented. The distinctness with next horizon is gradual, may be detected on the basis of the color.

Ph2 (92–110 см) – the second lower transition horizon. Light yellow with vertical humus spots. Consistence is compact. Light loam. Moist. The distinctness with next horizon is gradual, may be detected on the basis of the color, unclear.

Ph3 (110–140 cm) – the third lower transition horizon. Light yellow, lighter than the previous one, the marble from the enclosures of the humus spots. Light loam. Moist. The distinctness with next horizon is clear, may be detected on the basis of the color and texture.

P (140–180 cm) – parent material. Blue-gray clay sand. Very moist. Consistence is soft.

Pgl (180–200 cm) – gley parent material. Dark blue-gray sand with reddish spots. Consistence is soft.

The working definition of soil: sod gley soil (Gleysols (Humic)).

Sampling polygon № 25. The vegetation of poplar-willow forests (habitat type according EUNIS G1.1112 Eastern European poplar-willow forests) included a total of 38 species of vascular plants. The tree stand are dominated by *Populus alba* L. та *Ulmus laevis* Pall.. The shrub layer are dominated by *Acer tataricum* L., *Crataegus rhipidophylla* Gand., and *Sambucus nigra* L., the herbaceous layer are dominated by *Anthriscus cerefolium* (L.) Hoffm., *Galium aparine* L. та *Stellaria media* (L.) Vill. The total projective cover of herbaceous species is 25–30 %. For identification of plant communities, within which research was undertaken, we give it a syntaxonomy characteristic.

Class *Salicetea purpureae* Moor 1958
Ordo *Salicetalia purpureae* Moor 1958
Union *Salicion albae* R.Tx. 1955
All. *Populetum albae* Br.-Bl.1931

The soil invertebrates community included a total of 66 species representing 27 families and 10 orders and 6 classes from tree phylum (annelida, arthropods and molluscs) at the sampling polygon. *Carabus excellens* is included in the Red Book of Dnepropetrovsk region and *Carabus (s.str.) stscheglowi* (Mannerheim, 1827) is included in the Red Book of Ukraine (Sumarokov et al., 2018).

Soil profile description

The description was made in 5 May 2018 (additionally – 2 June) (Fig. 5, A). The poplar-willow forests in the floodplain of the inflow of Protich river (margin of the sand terrace of Dnipro river valley). The soil surface is relatively smooth. There is the litter consisted from leaves, not decayed, with a depth of 5–6 cm, projective cover is 90–100%. The projective cover of the grass layer is 25–30%. The parent material is alluvial sand. The groundwater level was 90 cm 5 May, 2 June the groundwater level was 122 cm. There are some traces of soil invertebrates activities, which are mixing horizons not exercise significant influence. There are no the visible soil neoformation, carbonate debris, accumulation of salts. Consistence is from friable to dense. The genetic profile type is humus differentiated. An intense carbonate effervescence after dilute hydrochloric acid treatment was occurred from the surface.

H_0 (6–0 cm) – organogenic, forest litter with projected cover 90–100%.

Hdk (0–7 cm) – upper soddy carbonate humus-accumulative horizon. Yellow-red (10YR 4/2), interspersed with sand particles, tightly intertwined by roots of herbaceous plants. Dry. Clay sand. The structure is grain-dust. Consistence is friable. There are no cracks. The distinctness with next horizon is clear, may be detected on the basis of the color and consistence.

H_k (7–35 cm) – humus-accumulative carbonate horizon. Blue-gray (5B 5/1) interspersed with sand particles. Consistence is friable, slightly moist. Clay sand. There are some roots of shrubs. There are no cracks. Structureless. The distinctness with next horizon is gradual, may be detected on the basis of the wetness and texture.

Hp_k (35–58 cm) – the upper transition carbonate horizon. Black (2.5Y 2.5/1). Consistence is friable, moist. Viscous, tacky. There are roots of shrubs. There are no cracks. Structureless. Consistence is dense. The distinctness with next horizon is gradual, may be detected on the basis of the color.

HP_k (58–80 cm) – the transition carbonate horizon. Gray (10YR 6/1) interspersed with light-gray (2.5Y 7/1) sand particles. Sandy loam. Moderate-

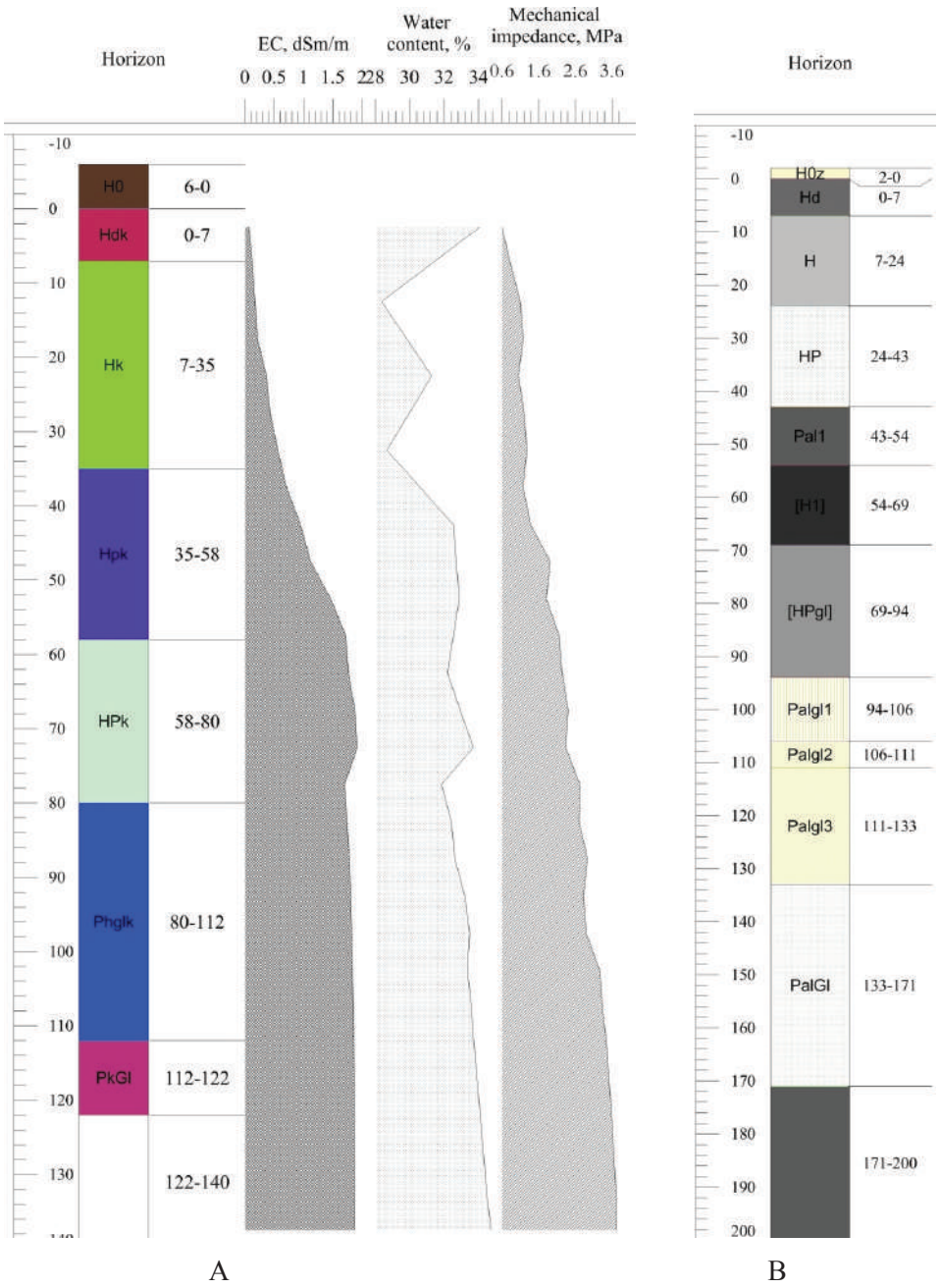

Fig. 5. The profile of alluvial meadow and forest deep loamy soil (Mollic Gleyic Fluvisol (Calcaric)) (A) and alluvial sod forest layered normal gley soil (Umbric Gleyic Fluvisol) (B)

Legend: A – H_0 – organogenic, Hdk – upper soddy carbonate humus-accumulative horizon, H_k – humus-accumulative carbonate horizon, Hp_k – the upper transition carbonate horizon, HP_k – the transition carbonate horizon, Phglk – the transition carbonate gleysolic horizon, PkGl – carbonate gleysolic parent material; B – H_{0z} – organogenic, H_d – upper soddy humus-accumulative horizon, H – humus-accumulative, HP – transition horizon, $P_{al}1$ – alluvial horizon, [H1] – the first buried humus-accumulative horizon, [HPgl] – the buried gleysolic humus-accumulative horizon, $P_{algl}1$– the fist alluvial gleysolic horizon, $P_{algl}2$ – the second alluvial gleysolic horizon, $P_{algl}3$ – the third alluvial gleysolic horizon, P_{alGl} – alluvial gleysolic parent material

ly moist. Densed. There are no roots of shrubs and cracks. The distinctness with next horizon is abrupt, may be detected on the basis of the consistence.

Phglk (80–112 cm) – the transition carbonate gleysolic horizon. Blue-gray (10B 5/1), gradually brightens with the depth, moist. A dense, almost merged, sticky and plastic. Sandy loam, there are no cracks. The distinctness with next horizon is abrupt, may be detected on the basis of the color and texture.

PkGl (112–122 см) – carbonate gleysolic parent material. Yellow (5Y 6/2) sand. Wet. Densed, consists of large lumps of sand that disintegrate when pressed. Bordered by subsoil waters.

The working definition of soil: alluvial meadow and forest deep loamy soil (Mollic Gleyic Fluvisol (Calcaric).

The alluvial sod soils are formed in riverine floodplain within the natural reserve "Dnipro-Orilsky" on layered sandy alluvium. There are four subtypes in type of alluvial soil: primitive sod, sod underdeveloped, sod short profile and sod valid (Nakonechny, Pozniak, 2011). The weak participation of groundwater water in water regime of profile through a limited lifting height of capillary water in the sands is peculiarity of this soil type. The signs of gleization are poorly expressed or absent. The short profile soil are the most common types (Manyuk, 2005). Alluvial sod soils are formed at the highest parts of the floodplain. Profile of soils consisting of three genetic horizons – humus-accumulative (H), transition (Ph) and parent material (P). Humus horizon is gray, wet, compacted (Nakonechny, 2016).

Sampling polygon № 26. The vegetation of flooded oak forest included a total of 60 species of vascular plants (Zhukov et al., 2017). The tree stand are dominated by *Quercus robur* та *Ulmus laevis*. The shrub layer are dominated by *Rubus caesius* та *Amorpha fruticosa*. The total projective cover of herbaceous species is 30–40 %. For identification of plant communities, within which research was undertaken, we give it a syntaxonomy characteristic.

Class ***Alno glutinosae-Populetea albae*** **P. Fukarek et Fabijanić 1968** (або ***Carpino-Fagetea*** **Passarge in Passarge et G. Hofmann 1968)**
Ordo *Alno-Fraxinetalia excelsioris* Passarge et G. Hofmann 1968
Union *Alnion incanae* Pawłowski, Sokołowski et Wallisch 1928
Subunion *Ulmenion minoris* Oberdorfer 1953 – дубово-в'язові заплавні ліси

The soil invertebrates community included a total of 34 species with a total abundance of 178.4 ± 26.9 ind./m^2 (Zhukov et al., 2018). The earthworm is a dominant group, which constitute 38.8% of the total community abundance. Earthworms are presented by four ecological types: litter dwelling *Dendrobaena octaedra*, two species of the endegeic *Aporrectodea trapezoides* and *Aporrectodea rosea* and one species of the anecic *Octodrilus transpadanus*.

Soil profile description

The description was made in 3 October 2017 (Fig. 5, B). The oak forest in the floodplain of the Dnipro river. The soil surface is relatively smooth. There is the litter consisted from leaves, not decayed, with a depth of 1.5–2 cm, projective cover is 30–40% digging extensively by boar. The parent material is alluvial sand. The groundwater level was 171 cm. There are no the visible soil neoformation, carbonate debris, accumulation of salts. Consistence is dense. The genetic profile type is humus differentiated. There is no a carbonate effervescence after dilute hydrochloric acid treatment.

H$_{0z}$ (2–0 cm) – organogenic, forest litter with projected cover 30–40 %, digging extensively by boar.

H$_d$ (0–7 cm) – upper soddy humus-accumulative horizon. Light-gray. Dry. Clay sand. Consistence is friable, tightly intertwined by roots of herbaceous plants. Structureless. The distinctness with next horizon is abrupt, may be detected on the basis of the consistence.

H (7–24 cm) – humus-accumulative. Light-gray. Slightly moist. Clay sand. Consistence is condensed, tightly intertwined by roots of herbaceous plants. Structureless. The distinctness with next horizon is graduated, may be detected on the basis of the consistence.

HP (24–43 cm) – transition horizon. Yellow-gray. Moderately moist. Clay sand. Structureless. Consistence is condensed. There are some roots of shrubs and trees. The distinctness with next horizon is abrupt, may be detected on the basis of the color.

P$_{al}$1 (43–54 cm) – alluvial horizon. Light-gray with rusty spots, which increase with depth. Sand. Slightly moist, structureless. There are occasionally vertical humus smudges. The distinctness with next horizon is diffuse, may be detected on the basis of the color.

[**H1**] (54–69 cm) – the first buried humus-accumulative horizon, structureless. Dark-gray. There are some roots. There are no cracks. Sand. Condensed. Slightly moist. There are occasionally vertical humus smudges. The distinctness with next horizon is graduated, may be detected on the basis of the color.

[**HPgl**] (69–94 cm) – the buried gleysolic humus-accumulative horizon. Dark-gray. ark red spots irregularly shaped 3-5 cm in diameter. There are some roots. There are no cracks. Sand. Condensed. Moderately moist. There are occasionally vertical humus smudges. The distinctness with next horizon is abrupt, may be detected on the basis of the color.

P$_{algl}$1 (94–106 cm) – the fist alluvial gleysolic horizon. Yellow-gray. Loose sand. Vertical humusovani smudges. The distinctness with next horizon is graduated, may be detected on the basis of the color.

P$_{algl}$2 (106–111 cm) – the second alluvial gleysolic horizon. Gray. Loose sand. Moderately moist. The distinctness with next horizon is graduated, may be detected on the basis of the color.

P$_{algl}$3 (111–133 cm) – the third alluvial gleysolic horizon. Red-rusty. Loose sand. Moderately moist.

The distinctness with next horizon is graduated, may be detected on the basis of the color.

$\mathbf{P}_{alGl}$ (133–171 cm) – alluvial gleysolic parent material. Sand. Moderately moist. Dark-blue-gray, loose.

The working definition of soil: alluvial sod forest layered normal gley soil (Umbric Gleyic Fluvisol).

Floodplains are among the most young and dynamic landscape elements. They were formed in the Holocene and continue to develop rapidly (Parkhomenko, 2015). Floodplain ecosystems are complex natural systems that characterized by a large spatial variability (Reddy, Patrick, 1993; Stolt, 2001; Rinklebe, Langer, 2006). The soils in the floodplain habitats are affected by erosion and the effects of sedimentation and transformation and translocation of substances which generally has the permanent effect, which forms veins and layers of sand or clay deposits, and varying degrees of accumulation of humus (Wälder et al., 2008). The floodplain soils are significantly affected by the underlying processes of rocks and parent materials, variability of standing groundwater, past and current velocity of water flow in the river, relief positions, approaching the river or dam and anthropogenic impacts (Wälder et al., 2008). Floodplain soils are seen as complex and polygenetical and polychronos formation, reflecting the long stages and litho-geomorphological paedogenesis and geological structure of river valleys (Mikhailyuk, 2001).

Floodplain of the Dnipro river is formed by furcation type. The genetic zones of the modern floodplain are formed due channel furcation, superimposed on genetic areas associated with the degree of remoteness from the mainstream, ie attenuation of alluvial tension. The floodplain relief is considered as segment systems within each of which formed riverine, floodplain and central plant conditions (Mirkin, 1974). The area of the floodplain is periodically covered by floodwater, after which the recession on soil surface is silt, which determines the morphological characteristics, properties and fertility of alluvial soils and lithology. The alluvial soils form a complex mosaic structure of soil cover due to unequal treatment of flood waters in different parts of the floodplain (Manyuk, 2005).

Conclusions

1. The biogeocenotic approach is the chain that connects the landscape structure, the diversity of soil cover, and diversities of the plant and animal communities. The functional, spatial and temporal properties of ecosystems in landscape context can be expressed by catena. Within the natural reserve «Dnipro-Orilsky» catena covers of the floodplain and sand terraces biogeocoenoses.

2. The biogeocoenosis concept is a basis for integration of the pedocatena, phytocatena and zoocatena. Catena approach is the framework for a monitoring system landscape diversity both at the level of individual component biogeocoenosis (edaphotop, phytocenosis, and zoocenosis) and biogeocoenosis level in terms of its horizontal and vertical structure and at the landscape level as a whole interconnected system.

3. The traditional idea of catena as a set of eluvial, transit and accumulative positions in a complex and diverse landscape is not able to cover the most important environmental gradients modes. The complexity of the landscape is due to relief diversity and the effects of anthropogenic transformation biogeocenotic cover. Catena therefore can be seen as a multilevel hierarchical system of the biogeocenotic polygons needed to consider the diversity of physiographic conditions and anthropogenic gradients.

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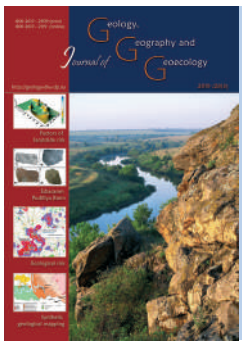

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Social and economic aspects of cross-border cooperation of Ukraine and Poland in the field of tourism

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Abstract. The research is devoted to the disclosure of socio-economic aspects of cross-border cooperation in the field of tourism of Ukraine and Poland, which is important in today's conditions of development of globalization processes and transformation of social relations. Such relationships are formed between people in different geographic areas, which determine their social mood and social behaviour. The signing of the visa-free travel agreement between Ukraine and the EU on 17 May 2017 and its entry into force on 11 June 2017 has become an important factor in the development of tourism in Ukraine and Poland, in particular within the border areas and in the context of cross-border cooperation of the Carpathian Euroregion. Tourists from Ukraine have better opportunities than before to travel to many European countries, and tourist migration contributes to the integration of peoples, building good-neighbourly relations and tolerance, economic, cultural, scientific and other forms of cooperation. That is why it is necessary to study the socio-economic aspects of the development of tourism in Ukraine and Poland at the level of the Carpathian Euroregion. The attention of the authors of this article is devoted to the study of the historical and cultural heritage of the four regions of Ukraine and the counties of Poland included in the Carpathian Euroregion as one of the important factors influencing the development of tourism. The article analyzes a number of key indicators of the activity of the subjects of the tourist market and the trends in their changes, as well as the geographical structure of tourist flows and the administrative and territorial division of the regions of the Ukrainian-Polish transboundary. Positive trends in the growth of a number of key indicators of tourism activity in Lviv region give reason to assert the high level of activity of tourism services market participants and that Lviv region has good preconditions for the development of many types of tourism , which can increase the flow of revenue to local budgets. Statistical materials of the Main Department of Statistics in Lviv Oblast have also made it possible to analyze the indicators for those areas that are part of the Carpathian Euroregion and characterize the specifics of the development of the tourism sector. It is proposed to form an updated marketing strategy for tourism management in Ukraine in the context of the changing conditions that have taken place in the tourist services market after the entry into force of the visa-free travel agreement between Ukraine and the EU, which will positively influence the development of tourism in Ukraine and Poland at the level of the Carpathian Euroregion.

Keywords: region; Carpathian Euroregion; tourism; regional cooperation; cross-border cooperation.

Суспільно-економічні аспекти транскордонного співробітництва України і Польщі у сфері туризму

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Анотація. Дослідження присвячене розкриттю суспільно-економічних аспектів транскордонного співробітництва у сфері туризму України і Польщі, що має важливе значення в сучасних умовах розвитку процесів глобалізації та трансформації суспільних відносин. Такі відносини формуються між людьми на різних географічних територіях, визначають їх суспільний настрій та соціальну поведінку. Підписання та введення в дію угоди про безвізовий режим України у 2017 році стало важливим чинником розвитку туризму в Україні та Польщі, зокрема у межах прикордонних територій та транскордонного співробітництва Карпатського Єврорегіону. Туристи з України отримали кращі можливості з організації подорожей до багатьох країн Європи. Туристична міграція сприяє інтеграції народів, побудові добросусідських відносин та толерантності,

економічному, культурному, науковому та іншим видам співробітництва. Саме тому виникла необхідність дослідження суспільно-економічних аспектів розвитку туризму України і Польщі на рівні Карпатського Єврорегіону. Увага авторів статті присвячена дослідженню історико-культурної спадщини чотирьох областей України та окремих повітів Польщі, що входять до Карпатського Єврорегіону, як одного з важливих чинників впливу на розвиток туризму. У статті досліджено низку основних показників діяльності суб'єктів туристичного ринку та тенденції їхніх змін, а також географічну структуру туристичних потоків і адміністративно-територіальний поділ регіонів українсько-польського транскордоння. Позитивні тенденції до зростання низки основних показників діяльності суб'єктів туристичної діяльності у Львівській області дають підстави стверджувати про високий рівень активності учасників ринку туристичних послуг, про те, що Львівська область має передумови для розвитку багатьох видів туризму і збільшення надходжень до місцевих бюджетів. Також проведений аналіз зміни динаміки показників по областях, які входять до Карпатського Єврорегіону та характеризують специфіку розвитку сфери туризму. Запропоновано сформувати оновлену маркетингову стратегію управління туризмом в Україні, у контексті зміни умов, які відбулися на ринку туристичних послуг після введення в дію угоди про безвізовий режим України та ЄС, що позитивно вплине на розвиток туризму України і Польщі на рівні Карпатського Єврорегіону.

Ключові слова: регіон; Карпатський Єврорегіон; туризм; регіональне співробітництво; транскордонне співробітництво.

Introduction. The processes of globalization and the transformation of social relations in society led to the following trends of its development: the emergence of global problems of the present, the formation of a global system of interconnections and interdependencies, the transformation of national cultures and people's consciousness, the formation of a transnational economy and politics, the development of information technologies, the creation of a global network of mass- media, etc. Studies of socio-economic relations in various branches of the economy, as a combination of forms of organization of common life of people, are of particular importance. Such relationships are formed between people in different geographic areas, in different organizations and institutions, shape their social mood in a certain period of time and determine their social behaviour. There are a number of risks that affect the behaviour of people in society, which can threaten their safety, health, social well-being, interaction with the environment, etc. Such risks are not limited to the geographical area or time period, and can also create financial and other risks from business activity. The socioeconomic risks, including those related to the development of tourism in the border areas, include image risks, whose determinants are traditions, national-cultural mentality, cross-culture and its interaction, politics, national ideas, virtual space, etc. For this reason, the studies of socio-economic aspects of tourism development in the Carpathian Euroregion on the example of Lviv Oblast of Ukraine and the Rzeszów County of Poland are relevant.

In today's conditions of functioning and development of tourism in different geographical areas of Ukraine and Poland, there are changes that were caused by various factors of influence: economic, political, social, scientific and technical, etc. It is worth noting that the migration factor is extremely important, including migration of the population of the border areas and their resettlement in other territories.

It should be noted that the signing and the entry into force of the visa-free regime between Ukraine and the EU in 2017 became a key factor in the development of tourism in Ukraine, especially in the border areas. Tourists from Ukraine have better opportunities than previously to travel to many European countries, and in the long run, a visa-free regime can be introduced with a number of other countries of the world, such as the countries of Latin America, Asia, etc. Advantages of tourist migration, including in the cross-border territories, are the creation of additional opportunities for freedom of movement, international integration of peoples, building good-neighbourly relations and tolerance, economic, cultural, scientific and other types of cooperation, improvement of cross-cultural interaction, and opportunities for their better socializing in a social environment, etc.

Activation of tourist migration has a number of positive aspects for both tourists and tour operators. There are also a number of tasks that need to be resolved regarding the activities of tourism in the border areas, including those that have appeared after the signing of the visa-free regime between Ukraine and the EU. The study of the functioning and development of tourism in Ukraine, Poland and separately in the Carpathian Euroregion has produced a significant number of scientific works of domestic and foreign scientists. The features that are typical for the development of tourism in the border territories and the tools of state reforms in this sphere are highlighted, directions of prospective development of cross-border cooperation in the field of tourism and problems that need to be solved are determined. But, despite considerable scientific progress, there is a need for further research on socio-economic aspects of development of tourism in Ukraine and Poland, at the regional level, taking into account a number of factors of influence, including factors of tourist migration of the population, which has become a "lifestyle" of the people, an element of their culture in

a global dimension.

The aim of the study. The aim of the article is to justify the socio-economic aspects of cross-border cooperation in the field of tourism of Ukraine and Poland, taking into account the factors of tourist migration after the signing of the visa-free travel agreement between Ukraine and the EU, as well as the development of a number of recommendations for implementation in practical activities that will provide a new stage for the successful development of the Carpathian Euroregion.

Materials and methods. Scientific research is executed on the basis of a number of regulatory documents regulating the activity and development of tourism in Ukraine as a whole, and the Carpathian Euroregion in particular, as well as statistical data of the Main Directorate of Statistics in Lviv Oblast, Lviv Oblast State Administration, Ministry of Economic Development and Trade of Ukraine, embassies of Ukraine in Poland and so on. It should be noted that from the Polish side, inter-regional Ukrainian-Polish cooperation is carried out with the assistance of the Ministry of Internal Affairs, the Ministry of Foreign Affairs, the Ministry of Regional Development. On the Ukrainian side, such cooperation is carried out with the assistance of the Ministry of Regional Development, Construction and Housing and Communal Services of Ukraine, the Ministry of Economic Development and Trade of Ukraine, the Ministry of Foreign Affairs of Ukraine, the Ministry of Infrastructure of Ukraine, regional state administrations, etc. The institutional mechanism of Ukrainian-Polish interregional cooperation was created: the Ukrainian-Polish Intergovernmental Coordination Council, which defines the general directions of interregional cooperation, participates in the development of joint programmes for the development of interregional cooperation, etc.

Results and discussion.

I. Geographical characteristics and objects of the historical and cultural heritage of the Carpathian Euroregion

For a more complete understanding of the main socio-economic aspects of cross-border cooperation between Ukraine and Poland, it is necessary to characterize the geographical location of the Carpathian region, its natural and climatic conditions, some objects of cultural heritage, as well as other preconditions that determine its functioning and development.

The Carpathian Mountains, in terms of geology, are young mountains. The Carpathian Mountains are divided into three parts: the Western, Eastern and Southern Carpathians. In the scientific literature (Petranivskyj & Rutynskyj, 2006; Rutynskyj & Stecjuk, 2008; Shkola, 2007), the Eastern and Western Carpathians are still classified as Slavic or Northern. It is not possible to make a clearcut identification of the nationalities living on the territory of the Carpathian region, but in most cases: 1) Poles, Slovaks, Ukrainians, Hungarians and Czechs live in the territory of the Western Carpathians; 2) in the territory of the Southern Carpathians - mostly Romanians; 3) in the territory of the Eastern Carpathians - mostly Ukrainians, and the territory itself is also called the Ukrainian Carpathians. The physical geography of the Ukrainian Carpathians is distinguished by the following characteristics: length - almost 280 km, average width - 100 km, area - 37 thousand km^2, the highest point is Mount Goverla (2061 m); the largest lake - Synevyr; climate - moderately continental. The western European part of the Ukrainian Carpathians passes the main European watershed, which divides the Baltic and the Black Sea basins. The following rivers begin in the Carpathians: Vistula, San and Western Bug, Dniester, Suceava, Styr, Horyn, Prut, Tisa, Cheremosh, etc. The Ukrainian Carpathians, according to the administrative division, includes the following regions (oblasts) Zakarpattia, Ivano-Frankivsk, Chernivtsi, and Lviv.

Within the scope of this article only a brief study of the historical and cultural heritage of Zakarpattia, Chernivtsi, Ivano-Frankivsk, Lviv oblasts of Ukraine, as well as the Rzeszów, Krosno and Przemyśl counties of the Podkarpackie Voivodeship of Poland are presented.

Research on historical and cultural monuments and museums of Zakarpattia Oblast shows that they belong to the XI-XIX centuries, namely: the ruins of the castle in the city of Khust (XI-XII centuries), Palanok Castle in the city of Mukachevo (XIV-XVI centuries), the Gothic Church in Berehove (XV century), the historical museum and St. Michael's Church in the city of Svaliava (XVI century.), Ascension Church in the village Yasinia Rakhiv Raion (XIX century) and others. There are a number of museums in Zakarpattia Oblast: historical, ethnographic, artistic, which are concentrated in the cities of Uzhhorod, Mukachevo, Khust, Svaliava, Rakhiv. Zakarpattia Oblast is represented by a number of resorts: Chynadiyovo, Shaian, Kvitka Polonyny, Solotvyno, Borzhava, Yaremche, Bukovel, Vorokhta, etc.

Ivano-Frankivsk Oblast is characterized by a rich historical and cultural heritage (XII-XII centuries), which includes the following objects: Church of St. Panteleimon (XII century.) in Shevchenkovo, Dolyna Raion, ruins of the castle in Halych (XIV century),

Maniavsky Skete (monastery near the village of Maniava) in Bohorodchanskyi Raion and the city hall in Ivano-Frankivsk (XVII century), Church of St. Nicholas (Rohatyn) (XVIII centuries). In Ivano-Frankivsk, the following museums are located and successfully functioning: geological, local history, literary, artistic, as well as the Museum of Education. The historical and cultural heritage of Ivano-Frankivsk Oblast is also represented in the cities of Sniatyn and Kolomyia and in the villages of Kosmach and Kryvorivnya (Petranivskyj & Rutynskyj, 2006).

Historical and architectural monuments of Chernivtsi Oblast are concentrated in Chernivtsi, as well as in Vyzhnytskyi, Khotynskyi and Kitsmanskyi Raion. The following objects are of interest to tourists: in Chernivtsi - City Hall, Botanical Garden, Armenian Church, Residence of Bukovinian and Dalmatian Metropolitans, Arboretum (XIX-XX centuries); as well as the fortress Khotyn (XIII-XVIII centuries), the museum-estate of G. Garas in Vashkivtsi, the museum-estate of I. Mykolaychuk in village Chortoryia, Ionian Church in the village Vikno (XIX cent.), Ascension Church and bell tower in village Luzhany (XV cent.), Cross Church and bell tower in village Pidvalne (XVI century) and others. Chernivtsi Oblast and the city of Chernivtsi offer the visitor museums of architecture and everyday life, local history, artistic, the literary-memorial museums of O. Kobylianska and Yu. Fedkovych, and others. (Rutynskyj & Stecjuk, 2008).

It should be noted that the significant contribution in the Carpathian region is made by the historical and cultural heritage of Lviv Oblast. Lviv, as a city of museums, and at the same time, a city-museum that attracts many tourists, both domestic and foreign. Tourist attractions in Lviv and Lviv Oblast include museums, art galleries, monuments of history and monumental art, castles, Orthodox and Roman Catholic churches, synagogues, monasteries, forts, reserves, archaeological sites, resort resources, monuments of the history of architecture of Lviv, etc. There are about 20 museums functioning here: national, historical, zoological, natural, literary, ethnographic and artistic crafts, archaeological, history of religion, folk architecture and everyday life, the pharmacy-museum, art gallery, the museum of defence architecture, etc. The heritage of prominent figures of the past can be found in the memorial and art museums of Ivan Franko, S. Lyudkevich, M. Shashkevich, S. Krushelnytska, L. Levytsky, O. Novakivsky, O. Kulchytska, I. Trush, and others. A significant contribution to the historical and cultural heritage is made by Pidhirtsi, Olesko, Zolochiv, Svirzhsky, Zhovkva, and Pomoriany castles. State reserves are located in Belz, Zhovkva, Nahuievychi, Olesko, Urych, Skole (Skole Beskids) and in the city of Lviv, as well as the natural reserve "Roztocze", which was introduced by UNESCO's decision to the World Network of Biosphere Reserves (Shkola, 2007). Tourist Lviv is represented by a number of theatres: Solomiya Krushelnytska Lviv State Academic Theatre of Opera and Ballet, Maria Zankovetska Theatre, Les Kurbas Theatre, Lesya Ukrainka Theatre, Academic Theatre Voskresinnia and others. The well-known health resorts of Lviv Oblast include the following: Truskavets, Skhidnytsia, Morshyn, Shklo, Nemyriv, Velykyi Liubin, Rozluch, Slavsk and others.

The current state of the sphere of protection of cultural heritage in Lviv Oblast, its problems and problems to be solved are presented in the programme "Protection and preservation of the cultural heritage of the Lviv region for the years 2018- 2020 ". In addition, the document defines the mechanisms and criteria for implementing the programme, as well as practical measures and financial support for its implementation. Accordingly, within the framework of the protection of the cultural heritage, the religious buildings which are listed on the UNESCO World Heritage List are also subject to restoration: St. George's Cathedral in Lviv, Descent of the Holy Spirit Church , St. George's Church in Drohobych and other objects in different districts of Lviv Oblast.

The analysis of the historical and cultural heritage of the Carpathian region of Poland should be carried out in conjunction with the International Association "Carpathian Euroregion" established in 1993. The relevant agreement, which defined the boundaries of this geographical entity, was signed in Debrecen, Hungary. The Carpathian Euroregion includes four regions of Ukraine (Lviv, Ivano-Frankivsk, Zakarpattia, Chernivtsi), as well as the Subcarpathian Voivodeship with its capital in Rzeszów, Poland.

Accordingly, the first Euroregions on the Ukrainian border were created namely with the participation of Poland: Carpathian Euroregion, Euroregion Bug. Currently, there are 10 government level structures that can be conventionally divided by geographical and administrative features into the following (Kalat & Demedjuk, 2017):

a) jointly formed with the EU member states (Carpathian Euroregion, Euroregion Bug, Lower Danube Euroregion, Superior Prut Euroregion);

b) jointly formed with non-member countries (Euroregion Dniester, Dnepr Euroregion, Slobozhanshchyna Euroregion, Yaroslavna Euroregion, Donbas Euroregion).

The Carpathian Euroregion is the most active region, its activities are aimed at the socio-economic development of the border areas through the support of cross-border cooperation in the economic, cultural, environmental, scientific and educational spheres.

Within the Carpathian Euroregion, from the Ukrainian side, the Association of Local Self-Governance "Euroregion Carpathians-Ukraine" is functioning effectively, which, through its project activity, attracts about UAH 1 million annually for the development of Ukrainian border regions from the EU Structural Funds. The mission of the Network for Local Development of the Carpathian Euroregion is to create a platform for the dissemination of best practices on local development and to develop common approaches to support local community initiatives, including the use of the instruments of cross-border and interregional cooperation ("Euroregion Carpathians - Ukraine", 2019).

The study of the potential of the recreational and natural resources of the Carpathian Euroregion of Poland showed that objects of interest to tourists are represented by churches and other religious architecture, the Bieszczady and Magura National Parks, a number of landscape parks and nature reserves, resorts, and so on. Famous resorts include Horyniec-Zdrój; Polańczyk; Iwonicz-Zdrój; Rymanów-Zdrój. The highest mountain is Tarnytsia (1346 m), and the territory has two large rivers: San and Wisłok. The historical and cultural heritage of the Carpathian region of Poland is also represented by a large variety of castles, palaces, churches, synagogues, museums, reserves, art galleries, etc. In Rzeszów County of Poland, tourists are able to visit the ethnographic museum named after F. Kotula, the Lubomirski Castle and the Lubomirski Palace (XVII-XVIII centuries), the Bernardine Church (XVII cent.), The Synagogue (XVII-XVIII centuries) and other objects of interest. Krosno County of Poland offers tourists the opportunity to explore the following historical and architectural monuments: the Franciscan Church (XV-XVII centuries), the Palace Ensemble of Mniszech (XVII-XVIII centuries), the Castle of the Kmyty (XVI century), the Town Hall (XVII-XIX centuries), fragments of defensive walls (XIII-XVII centuries). Extremely interesting are expositions in museums of local history, history, the oil industry, the museum of crafts and others. The historical heritage of Przemyśl County of Poland is represented by the following objects: churches of the Carmelites (XVII century), Jesuits (XVII cent.), Franciscans (XVII-XVIII centuries); the Lubomirski Palace (IXX century), the Cathedral (XVI-XVII c.), the buildings of the Market (XVI-XVII centuries), fortifications of the Przemyśl fortress (IXX-XX centuries), as well as local history, diocesan, national museums, etc. (Smal, 2010).

II. The regulatory legal framework for cross-border cooperation within the Carpathian Euroregion

The main principles related to joint projects and programmes of participants in cross-border cooperation, the goals and principles of their activities, organization and control of cross-border activities, state support for the development of cross-border cooperation, as well as financial support are provided in the Law of Ukraine on Cross-border Cooperation, 2004. According to this Law, the main categories of research are defined:

- Euroregion - an organizational form of cross-border cooperation carried out in accordance with bilateral or multilateral agreements on cross-border cooperation;

- cross-border cooperation - joint actions aimed at establishing and deepening economic, social, scientific, technological, environmental, cultural and other relations between the subjects and participants of such relations in Ukraine and the relevant actors and participants of such relations from neighbouring states within competence as defined by their national law.

In addition, the following normative and legal documents that coordinate and regulate activities in the field of cross-border cooperation include the following: Decree of the Cabinet of Ministers of Ukraine "On Approval of the State Programme for the Development of Cross-Border Cooperation for 2016-2020" (from August 23, 2016, No. 554) and "State Strategy for Regional Development for the Period till 2020" (from December 20, 2017 № 1089); Decree of the President of Ukraine "On the Strategy of Sustainable Development" Ukraine-2020 "(from January 12, 2015, No. 5); "Strategic Plan of the Ministry of Economic Development and Trade of Ukraine for 2017-2020" (from April 28, 2017); the strategies of development of "tourism and resorts for the period up to 2026" (from March 16, 2017 № 169-p) and "Lviv Oblast for the period until 2027".

Between Ukraine and Poland, there are a number of cross-border cooperation programmes and projects implemented in Lviv Oblast with the help of international technical assistance (Lviv State Regional Administration, 2019):

1) Poland-Belarus-Ukraine Cross-border Cooperation Programme 2014-2020 within the framework of the European Neighborhood Instrument. The overall objective of the programme is to support

cross-border development processes in the border regions of Poland, Belarus and Ukraine in accordance with the objectives of the European Neighborhood Instrument.

2) The Creative Europe Programme - an EU programme aimed at supporting cultural, creative and audiovisual sectors, travel (1.46 billion euros);

3) The project «The World Of Carpathian Rosettes - Activities For Preserving The Cultural Uniqueness Of The Carpathians».

4) The project «Cross-Border Pilgrimage Route as an Instrument of Promotion of Common Cultural and Historical Heritage on the Ukrainian-Polish Border Areas».

5) Project «B(L)ike Roztocze together in spite of borders».

6) The project «Bug unites us - creation of two cross-border tourist kayak trails".

Within the framework of the Trans-border Cooperation Programme "Poland-Belarus-Ukraine", grant agreements for the implementation of projects were signed at the Carpathian Euroregion Forum, which took place on October 3-4, 2018 in the Lviv Regional Council. The forum was attended by representatives of Transcarpathian, Lviv, Ivano-Frankivsk and Chernivtsi regional councils, as well as the State Secretary of the Ministry of Investment and Development of the Republic of Poland. The memorandum, which was signed at this event, provides for the possibility of renewed development of relations in the field of tourism between Ukraine and Poland. The Ministry of Regional Development and Trade of Ukraine presented the Carpathian Network for Regional Development Project at the Carpathian Euroregion Forum. This project was the winner of the competitive selection of regional development projects, which will be implemented at the expense of the state budget, received from the European Union within the framework of the programme of support of the sectoral policy - support of the regional policy of Ukraine. The budget of the project "Carpathian Network of Regional Development" UAH 48 million will jointly be implemented by the Ministry of Regional Development and Trade of Ukraine, Lviv, Zakarpattia, Ivano-Frankivsk and Chernivtsi regional state administrations and the Association of Local Self-government "Carpathian Euroregion - Ukraine". The purpose of the "Carpathian Network of Regional Development" project is to increase the efficiency of regional economic development in the Carpathians through the use of instruments of interregional cooperation (Lviv State Regional Administration, 2019).

Cooperation in the field of tourism, as well as cultural and humanitarian cooperation between Ukraine and Poland, is regulated by the existing contractual and legal framework of relations and creates favourable opportunities for its development. Created at the Embassy of Ukraine in the Republic of Poland, "the Centre for Culture and Information" promotes the dissemination in Poland of information about Ukraine, informs citizens about the possibilities of joint interaction between countries in various spheres, including the tourism sphere.

III. Analysis of the current state and trends of cross-border cooperation between Ukraine and Poland in the field of tourism

The study of the current state of functioning and trends of tourism development in the Carpathian Euroregion will be conducted on the basis of its division and comparison: Lviv, Ivano-Frankivsk, Zakarpattia, Chernivtsi region of Ukraine and Podkarpackie Voivodeship of Poland.

III.1. Lviv Oblast

Lviv Oblast has a well-developed infrastructure and numerous prerequisites for the development of many types of tourism and increased revenues to local budgets. Positive tendencies to the growth of a number of key indicators of the activity of subjects of tourism activity in the Lviv Oblast (Table 1) give reason to assert the high level of activity of participants of the market of tourist services.

Income from providing tourist services (excluding VAT, excise tax and similar obligatory payments) for the period under study has a tendency to increase. Thus, in 2016 compared to 2015, this indicator increased by 45.1%; in 2017 compared with 2016 - by 50.88%. The number of tourist trips for 2015-2017 also grew. According to the base indicator for 2015, in 2016 the growth was 105.06%; in 2017 compared with 2016 - by 12.28%.

According to the analysis of the geographical structure of tourist flows, organized by the subjects of tourist activity in the Lviv Oblast (Fig. 1) in 2017, Turkey, Egypt, Bulgaria, Greece, and other countries enjoyed the greatest popularity in the field of outbound tourism. The four most popular countries of origin for tourists visiting Ukraine in 2017 were Poland, Azerbaijan, Belarus and Germany. Most tourists who visited Lviv Oblast in 2017 were from Poland. This gives grounds for further development of cross-border cooperation in the Carpathian Euroregion as the main form of cooperation in the field of tourism between Ukraine and Poland.

It is worth paying attention to the extremely important fact that the number of people receiving services in health tourism in Lviv Oblast according to the general indicator in Ukraine (in %) was: 8.4%, of

Table 1. Analysis of the dynamics of the main indicators of the functioning of actors in tourism in Lviv Oblast, 2011-2017

Indicators	Years							Deviations 17/11	
	2011	2012	2013	2014	2015	2016	2017	Absolute value	%
The average number of full-time employees, persons	681	760	846	715	667	775	802	121	17.77
Those of them who have higher or secondary specialized education in the field of tourism	295	367	425	356	384	409	418	123	41.69
Revenues from the provision of tourist services, million UAH	114.1	176.7	228.7	174.8	188.7	273.8	413.1	299	262.05
Number of tourist trips sold, units	71,490	87,504	114,275	81,099	92,594	189,875	213,186	141,696	198.20
Cost of the realized tourist trips, million UAH	251.4	353.4	476.1	595.4	682.3	877.4	1312.1	1060.7	421.92
Average cost per ticket, UAH	3,517	4,032	4,167	7,342	7,368	4,621	6,155	2,638	75.01
Number of tourists for tourist trips sold, thousands	743.1	955.9	1,248.4	1,230.8	948.1	1,771.5	1,774.6	1,031.5	138.81
Average travel time per trip, days	10	11	11	15	10	9	8	-2	-20.00

Source: developed by the authors on the basis of statistical data of the Main Department of Statistics in Lviv Oblast

whom 31.2% were foreigners (2015), 7.4%, of whom 29.9% were foreigners (2016) and 7.6%, 32.6% of whom were foreigners (2017). This tendency gives grounds to believe that the activities of market participants in "therapeutic tourism" need to be intensified and improved. Therapeutic and tourist

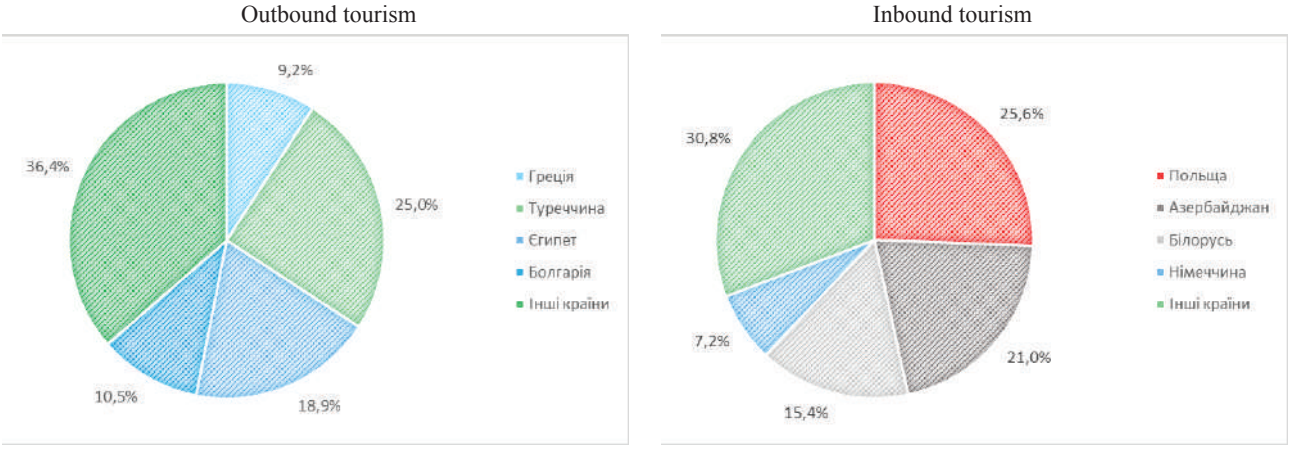

Fig. 1. Geographical structure of tourist flows, organized by subjects of tourist activity of Lviv Oblast, 2017
Source: developed by the authors on the basis of statistical data of the Main Department of Statistics in Lviv Oblast

complexes of Truskavets, Morshyn, Skhidnytsia and the private sector should jointly develop a set of practical measures that will increase the competitiveness of the tourist industry in the region.

III.2.1. Carpathian Euroregion, Ukrainian part

In the course of the research, we analyzed the dynamics of the share of the number of tourists from the Ukrainian part of the Carpathian Euroregion (Lviv, Zakarpattia, Ivano-Frankivsk, Chernivtsi oblasts of Ukraine) in the total number of tourists served by the subjects of tourist activity in Ukraine for 2015-2017 (Table 2).

According to the data of Table. 2, only Zakarpattia and Chernivtsi oblasts show an unbroken positive dynamic in the number of tourists. In Ivano-Frankivsk and Lviv oblasts, this indicator was reduced in 2017 compared to 2016, respectively, by 8%, 37% and 3.64% respectively. This situation requires the participants of the tourist services market of Ivano-Frankivsk and Lviv oblasts to intensify their activities to ensure its positive dynamic in the future. The total

Table 2. Analysis of the dynamics of the number of tourists served by the subjects of tourism activity in the Ukrainian part of the Carpathian Euroregion, 2015-2017.

Number of tourists served by subjects of tourism activity (in thousands)	Years			Deviations, %	
	2015	2016	2017	2016/2015	2017/2016
Zakarpattia Oblast	10.7	11.6	14.7	8.4	26.72
Ivano-Frankivsk Oblast	65.9	80.0	73.3	21.4	-8.37
Lviv Oblast	112.5	181.8	175.2	61.6	-3.64
Chernivtsi Oblast	15.7	19.4	20.3	23.57	4.64
Total: in the regions of the Ukrainian part of the Carpathian Euroregion	204.8	292.8	283.5	42.97	-3.18
Total: in Ukraine	2019.6	2549.6	2806.4	26.24	10.07

Source: developed by the authors on the basis of statistical data of the Main Department of Statistics in Lviv Oblast

number of tourists served by the subjects of tourist activity for 2015-2017 increased in the regions of the Ukrainian part of the Carpathian Euroregion (by 78.7 thousand people or 38.96%) and Ukraine in general (786.8 thousand people or 38.43%).

82.7 thousand people; in Chernivtsi Oblast - 13.7 thousand people, 16.2 thousand people and 19.1 thousand people. The aforementioned indicators of the dynamics of the number of Ukrainian tourists who travelled abroad during the investigated period

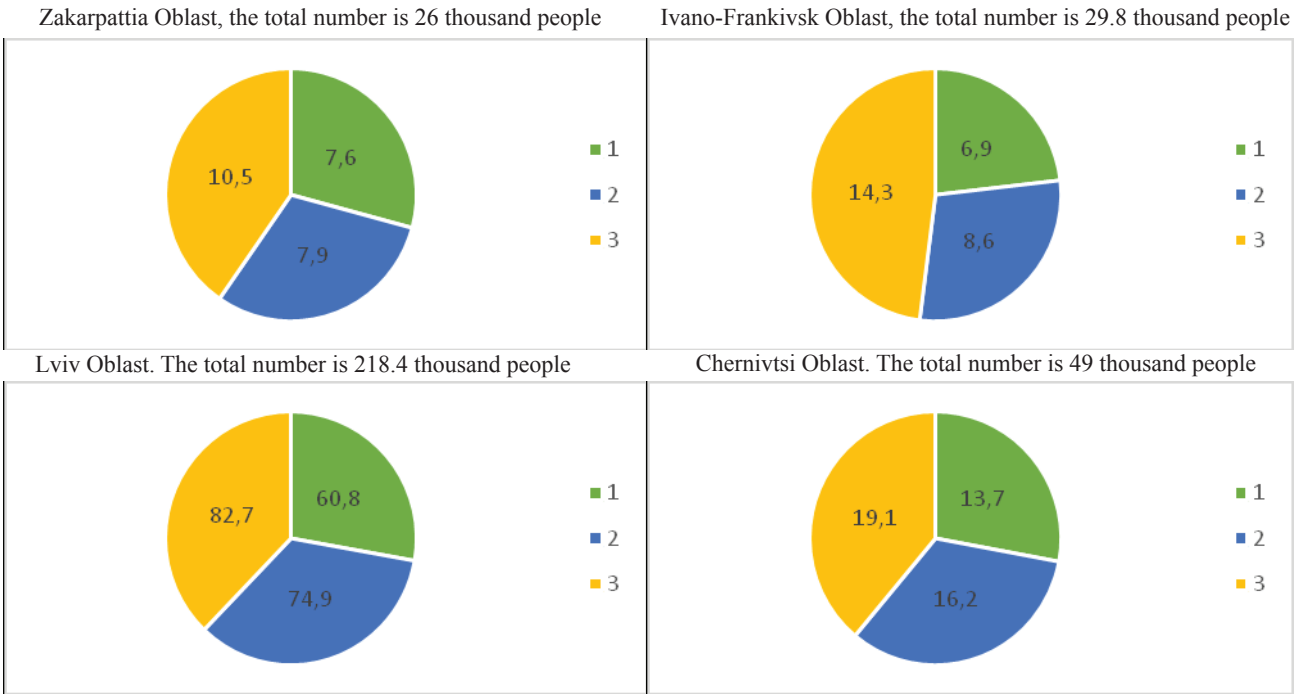

Fig. 2. Dynamics and structure of the number of Ukrainian tourists who travelled abroad, 2015-2017.

Legend: 1 - 2015; 2 - 2016; 3 - 2017 year.
Source: developed by the authors on the basis of statistical data of the Main Department of Statistics in Lviv Oblast

The dynamics and structure of the number of Ukrainian tourists who have travelled abroad in the last few years are presented in Fig. 2.

The number of Ukrainian tourists who travelled abroad in 2015, 2016 and 2017 in Zakarpattia Oblast amounted respectively to 7.6 thousand people, 7.9 thousand people and 10.5 thousand people; in Ivano-Frankivsk Oblast - 6.9 thousand people, 8.6 thousand people and 14.3 thousand people; in Lviv Oblast - 60.8 thousand people, 74.9 thousand people and

in the regions of Ukraine included in the Carpathian Euroregion testify to their growth.

III.2.2. Carpathian Euroregion, Polish part

The study of socio-economic aspects of cross-border cooperation in the field of tourism in Ukraine and Poland will begin with an analysis of geographical location (Fig. 3) and the administrative-territorial division of the regions of the Ukrainian-Polish borderland (Fig. 4).

The length of the border of Lviv region with

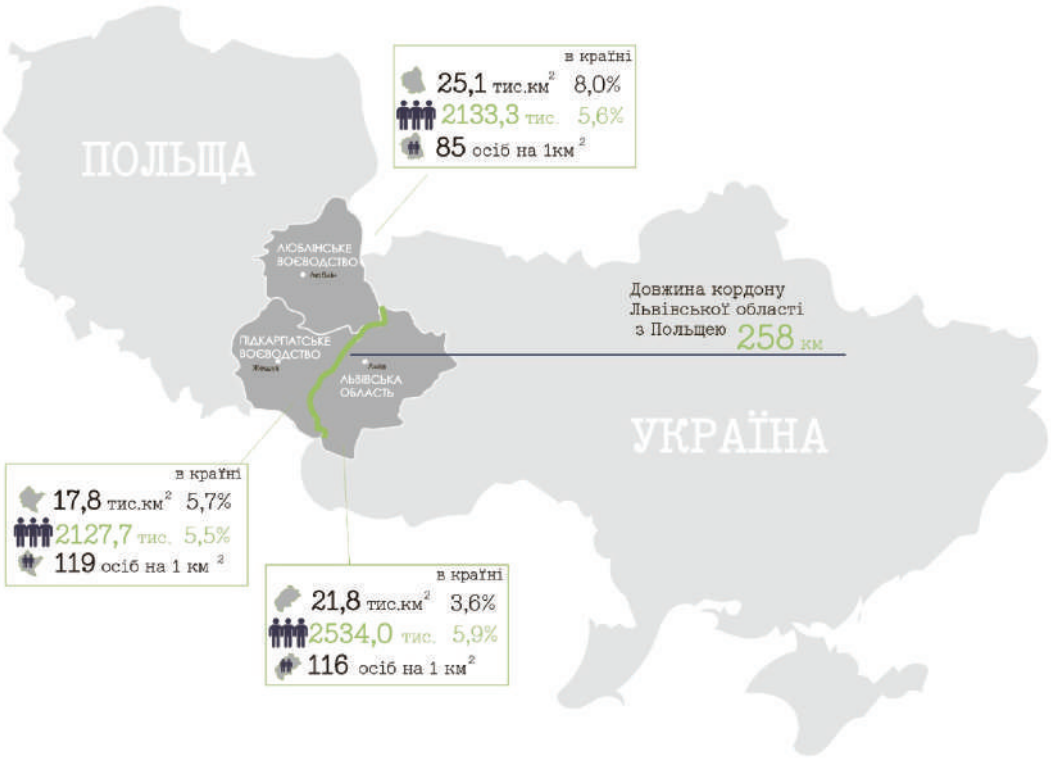

Fig. 3. Geographical map of the Ukrainian-Polish borderland
Source: L'vivs'ka oblast' u transkordonnomu prostori: statystychni indykatory [Lviv region in a cross-border area. Statistical Indicators] (2016). Ed. S. Zimovina. The Main Department of Statistics in Lviv Oblast. (in Ukrainian)

Fig. 4. Administrative-territorial division of the regions of the Ukrainian-Polish cross-border
Source: L'vivs'ka oblast' u transkordonnomu prostori: statystychni indykatory [Lviv region in a cross-border area. Statistical Indicators] (2016). Ed. S. Zimovina. The Main Department of Statistics in Lviv Oblast. (in Ukrainian)

Poland is 258 km. The part of the Polish part of the Carpathian Euroregion includes Podkarpackie Voivodeship, which includes 21 counties, 4 city counties, 51 towns and 1666 settlements.

Research on basic social and economic indicators of certain regions of the Ukrainian-Polish borderlands (Lviv Oblast, Podkarpackie and Lublin Voivodeships) and states (Ukraine and Poland) are presented in Table 3.

national economies of the respective states, in general, and at wage levels, in particular. Thus, the average monthly nominal salary in Lviv Oblast, Podkarpackie and Lublin voivodeships in 2016 amounted respectively to 161 euros; 838 euros; 875 euros. The number of subjects of the national economy in the same way in the Lviv Oblast, Podkarpackie and Lublin Voivodeships amounted to 163.2 thousand; 167.7 thousand; 174.1 thousand. These figures show that it is worth analyzing

Table 3. Basic socio-economic indicators of individual regions of the Ukrainian-Polish borderland and states, 2016

Indicators	Regions of the Ukrainian-Polish borderland			Total	
	Lviv Oblast	Podkarpackie Voivodeship	Lublin Voivodeship	Ukraine*	Poland
Area of territory, thousand km^2	21.8	17.8	25.1	603.5	312.7
The available population at the end of the year, thousand people	2,534.0	2,127.7	2,133.3	42,584.5	38,433.0
Per 1000 population: - natural increase (reduction) - migration increase (reduction)	-2.0	0.5	-1.2	-4.4	-0.2
	1.9	-0.8	-1.9	0.4	0.0
Students of higher educational institutions per 10 thousand people, persons	493	240	345	372	351
The number of tourists placed in collective accommodation per 1 thousand people, persons	340	522	429	154	784
GDP index, 2015 in % to 2014	95.2	103.6	101.2	90.2	103.8
Gross regional product per person**, in euros	1,541	7,929	7,666	1,916	11,184
The average monthly nominal salary, in euros***	161	838	875	183	984
Number of economic entities, thousands	163.2	167.7	174.1	2,789.2	4,237.7
Retail turnover for 1 person, euros***	954	2,522	2,534	974	4,504
Capital investment per person, euros***	261	1,068	806	299	1,458

* - Indicators are given without taking into account the temporarily-occupied territories of the Autonomous Republic of Crimea, the city of Sevastopol and the temporarily occupied territories of Donetsk and Luhansk Oblasts.
** - Data for 2015.
*** - Translated into euros at the average annual rate of the National Bank of Ukraine in 2015. 1 euro = UAH 24.2287, in 2016 1 euro = UAH 28.2919; in the Voivodeship of Poland, according to the average annual rate of the National Bank of Poland in 2015, EUR 1 = PLN 4.1889, in 2016 1 euro = PLN 4.3625.
Source: developed by the authors on the basis of L'vivs'ka oblast' u transkordonnomu prostori: statystychni indykatory [Lviv region in a cross-border area. Statistical Indicators] (2016). Ed. S. Zimovina. The Main Department of Statistics in Lviv Oblast. (in Ukrainian)

The number of students in higher education institutions, as a favourable factor for the Polish higher education system, is influenced by the visa-free regime of Ukraine and the EU. In addition, it creates enormous additional opportunities for Ukraine in the field of tourism development and cross-border cooperation between Ukraine and Poland. According to the data of Table. 3, the number of tourists accommodated in collective accommodation facilities per 1000 people, in Lviv Oblast, Podkarpackie and Lublin voivodships respectively was 340 people; 522 people; 429 people. To explain the tendency observed in these figures, it can be argued that it is necessary to find out the reasons for the figure in Lviv Oblast, namely which factors restrict the ability of the population to travel. These factors include the difference in the development of the conditions in which the subjects of the national economy of Ukraine and Poland operate, as well as offering a number of practical measures to increase the number of subjects of the national economies of Ukraine and Poland, which will contribute to the growth of the gross regional product, the retail turnover trade and capital investments, etc.

IV. Formation of the basic principles of development of the tourist industry of Ukraine

In accordance with the Strategic Plan of the Ministry of Economic Development and Trade of Ukraine for 2017-2020, a number of strategic goals aimed at creating the conditions for economic independence of the country were explored, including the task of forming the basic principles of sustainable development of tourism and resorts as a priority sector

of the country's economy. (Table 4).

According to Table 4, there is a positive dynamic on all the predictive indicators of realization of the task of forming the basic principles of the sustainable development of tourism and resorts of Ukraine. In particular, in 2019, the projected volume of foreign tourists, compared with 2018, should increase by 21.88%; in 2020 compared to 2019 by 7.69%. The planned increase in the number of subjects of tourism activity in 2019 compared to 2018 is expected to be

Table 4. Dynamics of the forecast indicators of the implementation of the task of forming the main principles of sustainable development of tourism and resorts as a priority sector of the country's economy, 2018-2020.

Objective name	Name of the indicator of the result to be achieved	Planned period, years		
		2018	2019	2020
TASK 3.4. Formation of the basic principles of sustainable development of tourism and resorts as a priority sector of the country's economy*(Deregulation and enterprise development and competition *)*	number of foreign tourists entering Ukraine, million people *	16	19.5	21.0
	number of subjects of tourist activity, thousand units	9.5	10.2	11.5
	receipt to the local budgets of funds from the payment of tourist fees, UAH million	62.0	74.2	85.0
	receipts to the consolidated budget (taxes and fees) from activities of subjects of tourism activity, UAH billions	2.8	3.4	4.5
	number of jobs in the field of tourism, thousand persons *	115.0	132.0	150
	number of domestic tourists, thousand persons	600.0	714.0	1000
	number of participants in excursions, thousand persons	165.0	187.5	250.0

* The medium-term plan of the Government's priority actions by 2020 (approved by the Cabinet of Ministers of Ukraine dated April 3, 2017, No. 275).

Source: Developed by the authors on the basis of Strategichnyj plan Ministerstva ekonomichnogo rozvytku i torgivli Ukrai'ny na 2017-2020 roky [The Strategic Plan of the Ministry of Economic Development and Trade of Ukraine for 2017–2020] from April 28, 2017 (2017). Retrieved from: http://www.me.gov.ua/?lang=uk-UA; file:///C:/Users/HomE/Downloads/Стратегічний_план_МЕРТ_(28.04.2017)%20(2).pdf. (in Ukrainian)

7.37%, and in 2020, compared with 2019 12.75%. In accordance with the task, a number of practical measures have been developed that should ensure the realization of the set goals. Practical measures include those that involve the creation of Internet portals "Visit Ukraine" and making them available in foreign languages; creation of a national network of tourist brands of Ukraine; making changes to the laws of Ukraine "On Tourism" and "On Resorts"; raising the level of Ukraine's presence at international events; creation of an interactive layer database etc.

Conclusions. According to the results of research on the socio-economic aspects of cross-border cooperation in the field of tourism in Ukraine and Poland, the following should be noted:

- the signing and the entry into force of the visa-free regime between Ukraine and the EU in 2017 resulted in a new stage in the development of tourism in Ukraine; tourist migration intensified, which resulted in the appearance of additional positive aspects for the joint interaction of tour operators;

- tourism migration should be considered as an important factor in the development of cross-border cooperation, building good-neighbourly relations and tolerance between Poland, Ukraine and other states with common borders;

- an important factor contributing to the development of cross-border cooperation in the field of tourism of Ukraine and Poland is the geographical location of the Carpathian region, its natural and climatic conditions, the rich historical and cultural heritage of the countries, cross-cultural interaction, community mentality of citizens, etc;

- at the state level, four oblasts of Ukraine (Lviv, Zakarpattia, Ivano-Frankivsk, Chernivtsi) and Podkarpackie Voivodeship of Poland (Rzeszów, Krosno, Przemyśl County) effectively carry out cross-border cooperation in accordance with the developed regulatory legal documents, joint programmes and projects, with the assistance of EU, including for the funds of Ukraine, Poland and the EU;

- the study of some economic indicators, according to the data of the Main Department of Statistics in Lviv Oblast and the revealed trends of their changes, as well as materials from official sites of a number of institutions and organizations, suggests that the potential for improving the socio-economic aspects of cross-border cooperation in the field of tourism in Ukraine and Poland does exist, this should be used with active cooperation, with the benefit both for the

countries as a whole, and for all participants of the market of tourist services, in particular.

In the course of the study, a number of recommendations were formulated to improve the efficiency of cross-border cooperation in the field of tourism of Ukraine and Poland for their implementation into practical activities:

1. To form an updated marketing strategy for managing internal , inbound and outbound tourism in Ukraine in the context of changes in the conditions of the tourist services market that took place after the entry into force of the visa-free regime between Ukraine and the EU. Determine the conditions for preferences regarding tourism market activities for market participants, who are leaders in Ukraine in domestic and inbound tourism. Activate the activities of market participants in tourism services for domestic and inbound tourism, as well as for "green tourism". Develop a set of practical measures, with the assistance of territorial communities, which will increase the competitiveness of the tourism industry in the development of the resorts Truskavets, Morshyn, Skhidnytsya, as well as new tourist facilities.

2. To harmonize the legal framework concerning the use of the nature reserve fund in Ukraine for tourist purposes.

3. Develop a geographic map and make it available online, which will promote a higher level of tourist safety, which will reduce the number of tourists who are involved , for various reasons , in dangerous situations during their trip.

4. To implement the Law of Ukraine "On Social Tourism", with the purpose of expanding resources for individual development of socially vulnerable categories of the population, their better adaptation in society; to attract in this context the effective interaction of employers, etc.; to develop and implement regulatory documents that would encourage employers to invest in individual development of personnel, including through the existing system of purchasing tourist services at the expense of enterprises or on the terms of participation of employees.

5. Within the framework of the curricula of higher education institutions of Ukraine which train specialists for the sphere of tourism, to study topics related to cross-border cooperation in the field of tourism.

6. To develop a more effective mechanism for the development of tourism infrastructure, as a result of changes after the entry into force of the visa-free regime between Ukraine and the EU.

7. Provide information on the «Programmes" and "Projects" on the websites of the state authorities of Ukraine (villages, settlements, cities, rayons, regional councils, Lviv regional state administrations) and Poland (gminas, counties, voivodeships) which refer to cross-border cooperation, the possibilities of participation of territorial communities, etc.

8. To implement practically planned projects of Ukraine and Poland in the interests of participants of these projects, which will provide a number of advantages, namely: effective development of border areas, including mountain and rural areas; accelerate the economic growthof both countries ; increase the quality of life of the population; promote better mutual understanding among peoples.

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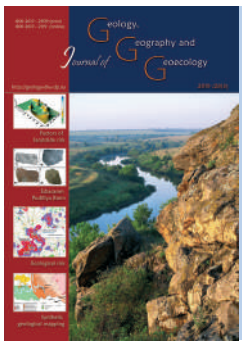

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Analysis of environmental factors' effect on the development of tourism

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Abstract. Balancing of the tourism services' development and natural environment' opportunities is problem during anthropogenic effect is increasing. Migration of the population is increasing with the growing of the globalization process. As a result there is a duality in the development of tourist infrastructure and increasing the influence of tourists on ecology, changing of ecosystem. The article deals with the factors influencing the choice of tourists, tourist flows, analysis of the countries, where there is the greatest attendance of places of the rest. The correlation coefficient between indicators of environmental safety and tourists' attendance is calculated. On the example of the Kyiv region, dynamic indicators and the relationship between emissions of harmful substances and environmental costs, as well as the number of tourists, were calculated. Three recreation areas on the Black Sea coast in the territory of three different countries are analyzed. Conclusions about different degrees of water's and coastal area's pollution and the Odessa coast's pollution as a whole are made. Pollution of the Black Sea whole loch affects on the environment degradation of cross-border territories and tends to dampen the attractiveness for the recreation's development of the sea rest. The analysis of pollutant emissions and the accumulated waste in the Odessa region is made and the anthropogenic effect on the coastal areas of the Black Sea region in Ukraine, Bulgaria and Romania is compared. The consequences of austerity on the environment preservation are explored and described. It leads to losses that are arise from decrease of the employability of local inhabitants and their diseases, of natural resources' depletion, increasing of probability of natural disasters in the long term. In the article the conclusions about the effect of the tourists' traffic and its' influence on the ecology of the recreation areas and the slow anthropogenic impact on the new territories are made. The ways and solutions of modernization and reconstruction of the objects of the tourism infrastructure are suggested. They should to aim at increasing of the tourism's traffic and enhance new and modern buildings of the recreation infrastructure.

Keywords: tourism, tourism ecology, environmental performance index, countries of the Black Sea Region, waste, anthropogenic load, tourist potential, and tourist traffic.

Аналіз впливу екологічних факторів на розвиток туризму

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Анотація. Збалансування розвитку туристичних послуг та можливостей природного середовища залишається актуальною проблемою через зростання антропогенного впливу. З розвитком процесу глобалізації збільшується міграція населення, в наслідок чого виникає дуальність у розвитку туристичної інфраструктури та посилення впливу туристів на екологію із зміною екосистеми. У статті проаналізовано чинники, що впливають на вибір туристів, туристичні потоки, аналіз країн світу, де є найбільша відвідуваність місць відпочинку. Розраховано коефіцієнт кореляції між показниками екологічної безпеки та

відвідуваності туристів. На прикладі Київської області розраховувались динамічні показники та залежність між викидами шкідливих речовин і екологічними витратами, а також кількістю туристів. Проаналізовано три рекреаційних пункти на узбережжі Чорного моря на території трьох різних країн. Зроблено висновки щодо різних ступенів забруднення води та прибережної території і узбережжя Одеси. Забруднення акваторії Чорного моря впливає на погіршення екологічної ситуації трансграничних територій і знижує привабливість цих регіонів для розвитку морського відпочинку. Проведено аналіз викидів забруднюючих речовин та кількості накопичених відходів в Одеській області та порівнюється антропогенний вплив на прибережні території Причорноморського регіону в Україні, Болгарії та Румунії. Розкрито наслідки економії на збереженні навколишнього середовища, що в довгостроковій перспективі утворюю збитки, спричиненні зменшенням працездатності населення, виснаженням природним ресурсів, збільшенням вірогідності стихійних явищ та захворюваності населення. Зроблені висновки про вплив туристичних потоків на стан екології місць відпочинку і поступове розширення антропогенного впливу на незаймані територій. Запропоновано напрями модернізації та реконструкції існуючої матеріально-технічної бази об'єктів туристичної інфраструктури через сприяння будівництва нових сучасних об'єктів туристично-рекреаційної інфраструктури.

Ключові слова: туризм, екологія туризму, індекс екологічної ефективності, країни Причорномор'я, відходи, антропогенне навантаження, туристичний потенціал, туристичні потоки.

Introduction. The ecological problems are mostly due to the human activity and are long-term. Any interaction environment and human which changing the ecosystem has own results and may have cumulative effect. Before the twentieth century the environment was believed to regenerate itself and in conditions of the low strain could come into state of balance. But in conditions of more strong negative strain of human's being and the growing of his livelihoods and landscape modification the ecosystem hasn't reserves for balance and stabilization. And deterioration of the environment could lead to the decrease of the degree of the environmental safety. Needs for rest in the conditions of the high stress of human under urbanization have a fist position in modern society, and looking for the ways of the harmonization between recreation area and consumers' wishes made tourism one of the profitable business. It is filling the country's GDP but at the same time it is changing the ecosystem. Often the recreation areas are clear territories and have aesthetic advantages or cultural heritage and, in the majority, have a positive effect on the health of men who are coming to rest. The direction of the tourists' traffic depends on many factors, but however, a constant mass of people has negative affects on the natural environment, which is influencing by constant anthropogenic effects and is worsening, so it leads to the deteriorating competitiveness of these territories. Depletion of natural resources, destruction of historical and cultural values, changes of economic strategy of regions are also become the results of the mass tourism. Under the Globalization the migration of population is increasing and because of it two main trends are appearing – from the one hand, duality in the tourist infrastructure's development is being and, from the other hand, the tourists' influence on the ecosystem and its changes is growing. Tourism is one of the branches of economy of the Black Sea Region, and it's based on the temporary admission for health, cultural, professional, business or other purposes without having business in the place of staying (Kuzik, 2011).

The Black Sea coast is one of the leaders of the international tourism in Eastern Europe and it affects the natural environment of the countries that it is washed around (Ukraine, Romania, and Bulgaria). Allotments on tourism development, maintenance of historical and archaeological finds and places of recreation are not enough and, as a rule, become a business. Most types of tourism have a positive effect on the social and economic well-being of those territories where they are developing, but often they lead to the environmental and anthropogenic problems (Kostetska, 2018).

The aim of the article is to analyze the modern stage of the touristic branch and main factors of influence on the tourism traffic in the different countries, to identify the anthropogenic effect on the recreation areas, to comparative recreation areas with the same nature conditions, but different economic state and stress, and so to give the advance estimate of the recourse opportunities of this type in the field of the research.

Analysis of publication. Methods of analysis, synthesis, comparison, general environmental value, mathematical modelling, statistical, methods of valuation and monitoring are used in this article.

Despite the tourism and rest popularity, anthropogenic effect on the tourism recreation isn't explored enough (Barros, 2015). Natural environment hasn't enough recourse for regeneration and is constantly impoverished, but the increasing anthropogenic impacts and globalisation may lead to catastrophic results (Mowforth et al., 2015). In human influence on the recreation areas needs to take into account the degree of such influence, and mainly it depends on the number of vacationers. Tourist traffics depend on many factors. Petrova and others (Petrova et al, 2018) believe that the price for the rest is a major factor of affecting the choice of tourists and depends on the cost of travel to the rest zone and the cost of

living in a place of rest.

Bolan (2008) and others outline, that the main factors that influence the consumer's choice in the field of tourism are the image of places of recreation, advertising in products of the film industry and the mass media.

Today the popularity of social networks that have a set of advertising and influence the choice of product or service is increasing all over the world. Exploring the influence of social networks on the choice of tourists and the importance of advertising services in the choice, Park (2016) and others have concluded that the level of the tourism's development is correlated with the development of innovation and tourism infrastructure. It should also be noticed that the development of innovation in any branches of business has a very positive effect on the innovation of the whole national economy (Pukala, 2016; Odinokova, 2019).

Results. According to the State Statistics Service of Ukraine in 2015 the transfers from the state budget on innovation were decreased in 6.25 times in comparing with the previous year, the amount of own funds on innovation, increased in 2.05 times, reaching UAH 13,427 bln and share of 97% of the total costs (Labunska et al, 2017). In the analysis of state programmes and investment proposals (Petrova et al, 2018; Lukjanova, 2019), all strategies except of two ones are focusing on the development of local infrastructure and the promotion of travel for residents within the country, regardless of the country's specialisation in a particular type of tourism and international trade practices in the field of services. In addition, the value chain of the tourism product is realized both at the national and global level (Koval et al., 2019a). In conditions of the growing of the population's welfare, the level of education and changing citizens' interests and values, their free time encourages, as well as the opportunity to spend this time on active rest appear. So the number of tourists around the world is increasing and the impact on the natural environment increasing too. The tourism economy in many countries is of a short-term (seasonal) and is mostly based on the private business, when the purpose is to maximise profits with minimise the costs.

Long-term forecast of tourist flows is very important for investment planning in the tourism business (Koval et al., 2018), which is directly related to the attractiveness of the regions and the ability to effectively implement migration policy and solve environmental problems. Determining the attractiveness of recreational zones, first of all it needs to analyze the properties of tourist traffic in these areas, which basis on the estimation of the number of visitors, the degree of human-induced effects, the volume of tourist consumption and other indicators.

Analysing the tourist flows, it needs to study the consumers' purpose and the attractiveness of recreation areas. Let looking the factors of influence on the development of the recreation area (Fig. 1).

The main factors which influence on choosing of the place of the rest are:

Exclusivity that characters the degree of using of exotic, not standardised, non-unified, original outsourced services in a particular tourist product (Borysova, Borysova, 2019).

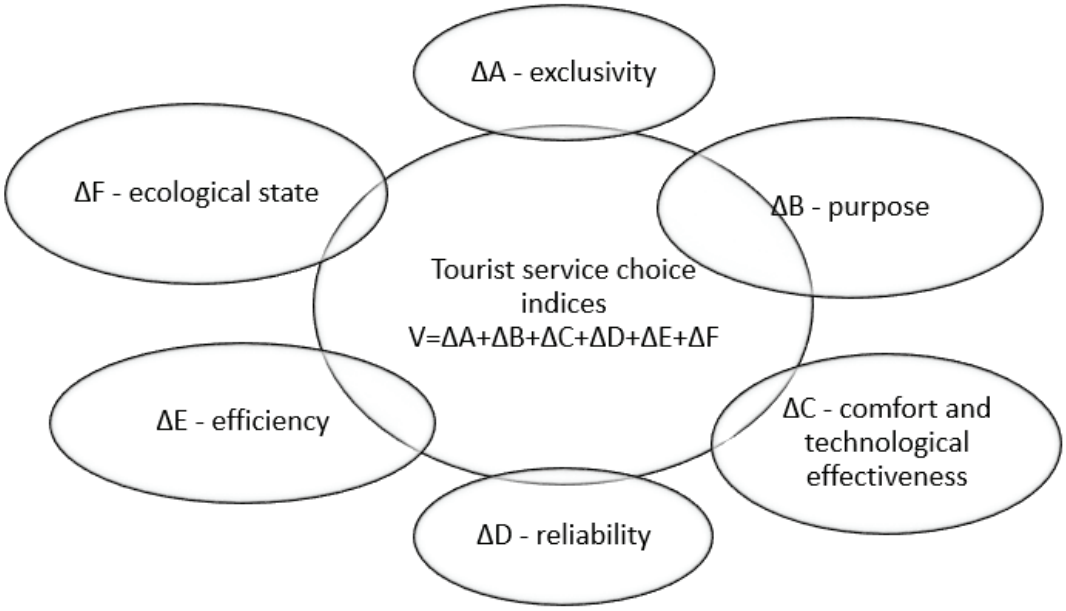

Fig. 1. Factors influencing the choice of a recreation area for the average consumer. Source: complied by the authors

Exclusive services mean services, offered only for this tourist product. The exclusivity indicators are important for a particular segment of tourism services. In case of an individual tourism programme, these indicators will be one of the key in the customer's decision to buy the offered service. Exclusivity is typical for the segment of high-value travel programmes that don't fit into the framework of the standard offer. The exclusivity indicators show the uniqueness and individuality of this tourist product (Baev, 2012).

Direction, which characterises the customer's targets of travel and wishes in choosing a recreation area (sea vacation, mountains, health improvement).

Aesthetic component that reflects the harmony, integrity of the coverage of the tourist programme, compliance with the social expectations, the level of skill of the staff and is a complex picture that comes from the person's senses.

The indicator of comfort and technological effectiveness, which includes both climatic conditions and the recreation area level according the factors of quality of services, infrastructure development, equipment, additional services, etc. First of all, the staff's professionalism, the internal culture of the organisation, the business philosophy, and other factors of the technological factor.

The reliability indicator, based on the person's wishes to stay in a safe place, and guarantees the fulfilment of all conditions of staying in the recreation area.

The indicator of economic efficiency which taking into account price parameters and its correspondence of quality of received services.

The indicators of the ecological state of the recreation area, which may include the atmospheric air, water resources, the presence of places of ecological anthropogenic load, the availability of waste accumulation territories and the general level of littering of the territory, etc. (Koval et al., 2019b).

To calculate the attractiveness of the recreational area, such indicators as statistics of tourist traffic and statistics of tourist income and expenses are used. Compared to the arrival statistic, which gives the general idea of the volume of tourist flows, there is statistic of the stay duration, which includes the characteristics of tourist trips. It help to take an information about transit and final trips and to used it in studying the demand of different groups of tourists for accommodation services.

Since 2008 the Environmental Performance Index (EPI) has been calculated. It is the quantification and benchmarking of environmental policy indicators in 180 countries all over the world. The EPI ranked countries according the effectiveness in several categories, which are grouped into two groups: ecosystem viability and environmental health (Hsu, 2014). The following indicators are analysed: environmental health; air pollution affecting human health; air pollution affecting the condition of ecosystems; water (which affects human health); water resources (affecting the ecosystem); biodiversity; forest; fishing; agriculture; climate change and energy (Athanasoglou, 2014).

In the Fig.2 we see, in comparison with 2016, in 2018 the situation has deteriorated in all countries, except Switzerland, what became the leader in the environmental performance index in 2018. This fact demonstrates the ecological and economic stability of this country and the development of technologies of economic attractiveness. But in general case there is a deterioration of the situation all over the world. In particular, low incomes countries are the most affected by the inability to use environmental standards, low health indicators and other factors of the quality of population's life. Often, such countries are suppliers of raw materials and other resources, a place of accumulation of environmentally dangerous enterprises with a low level of remuneration. Countries with the high environmental standards such as Switzerland, where the financial institutions are the main source of incomes, are more stable and have high living standards, which create favorable conditions for local residents. With further depletion of natural resources and deterioration of the ecological state, the situation will change in the negative side, affecting public health and creating additional risks, reducing work capacity and thereby worsening the country's potential. We will have a situation when the consequences of austerity on the environment preservation lead to losses that are arise from decrease of the employability of local inhabitants and their diseases (hospital vacations, increased mortality and childhood diseases), of natural resources' depletion, increasing of probability of natural disasters (flood, desert, fire and etc.) in the long term (Kvach et al., 2018).

If we analyze the EPI index and GDP we can make a conclusion about that there is a direct close link between them. We see, when economic situation of the state is better, the costs of improving the environment are increasing. When analyzing EPI indicators and the number of tourists arriving in Fig. 3 we found a weak dependence.

The correlation coefficient is 0.41, which indicates that the quality of the environment affects

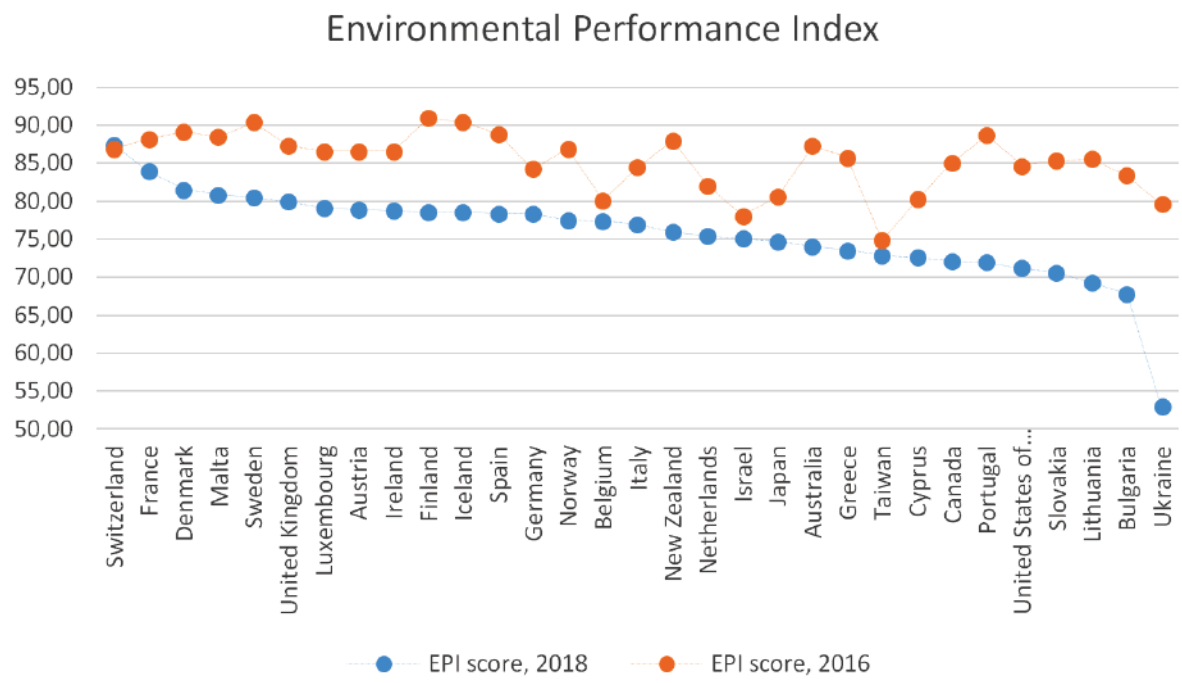

Fig. 2. Environmental Performance Index in different countries. Source: complied by the authors according to Wendling et al. (2018)

the choice of tourist destinations and is one of the factors of determination of the consumer's choice of the tourist services. However, a small indicator of dependence shows that other factors of choosing of a place of rest have impression too. Let see the influence of the ecological factors on the tourism development on the example of Kiyv Region in detail. The correlation coefficient between the current costs on the environmental security and the amount of the contaminants' emission is 0.54 (Fig.4) and it shows the direct middle connection between the exploring index. However, continuous accumulation of contaminants is reducing the attractiveness of this region as the recreation area. Allocation is not enough

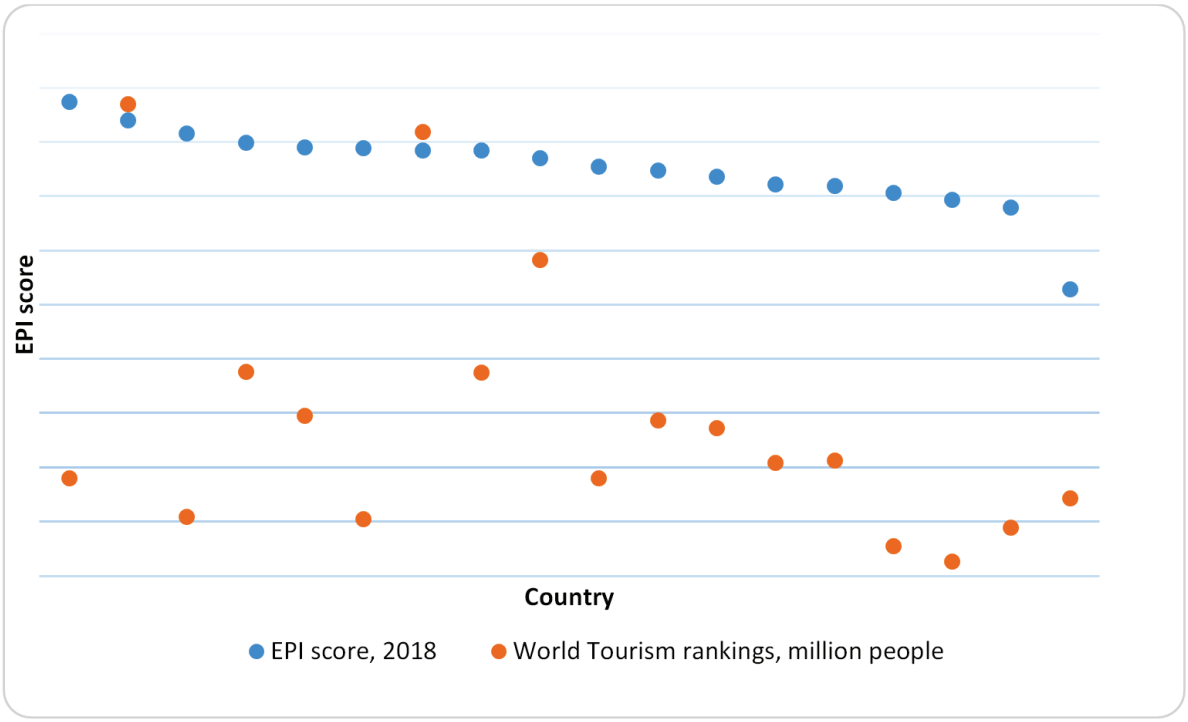

Fig. 3. Environmental performance indices and the number of arriving tourists in 2018
Source: complied by the authors according to Wendling et al. (2018)

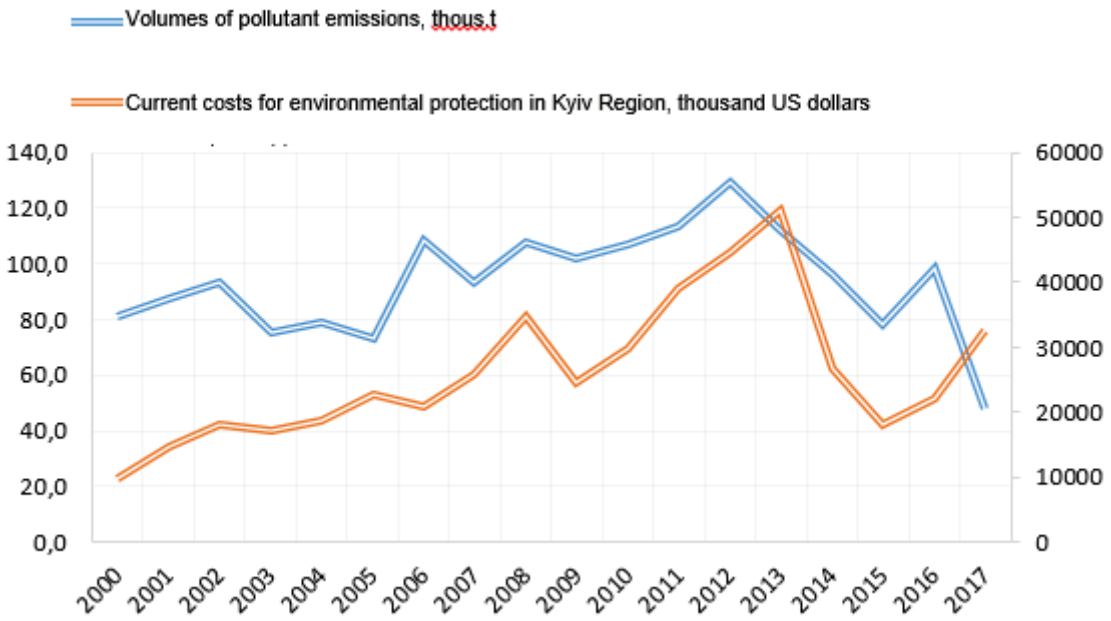

Fig. 4. Dynamics of pollutant emissions and current costs of the environmental protection in Kyiv Region
Source: complied by the authors according to State statistics service of Ukraine (2018)

to stabilize the environment, and private entrepreneurs often don't care about the environment and try to maximize profits by minimizing costs.

In 2017, we have a deviation from the general trend: current costs have increased with the emission reduction of pollutions. However, this doesn't mean improvement of the environmental situation, because of the corruption schemes and imperfection of the control authorities for the using of monetary resources, a significant part of the funding doesn't reach its purpose, and the effect of accumulation of toxic substances and the continuous deterioration of the ecological state are continuous. However, the amount of pollutions has decreased because of the decreasing of the production and economic instability in the country. But in Kiyv Region the service sector is rapidly expanding that has less impact on the ecosystem and gives a hope to improve the environmental situation and reduce the depletion of natural resources.

In the Kyiv Region there is an increase of tourists (Fig. 5). However, the tourist potential of Kyiv Region is increasing due to the factors of influence such as cultural, historical and business, which increases the

Fig. 5. Number of tourists arriving in Kyiv Region, served by the tour operators. Source: complied by the authors according to State statistics service of Ukraine (2018)

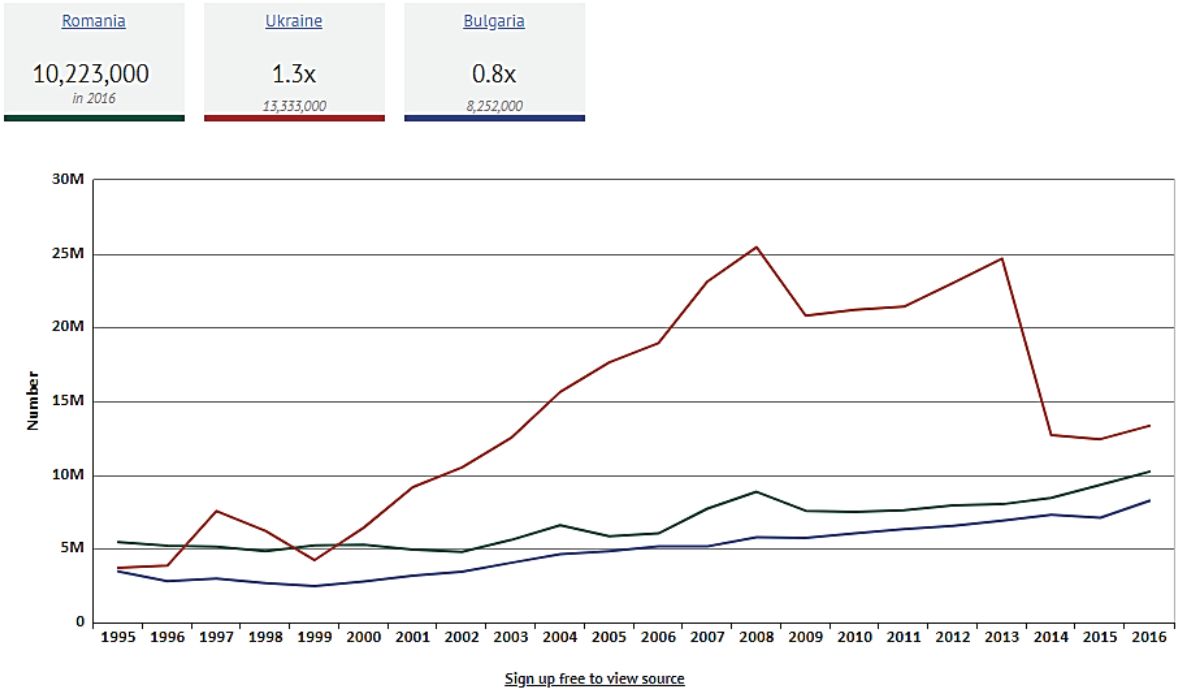

Fig. 6. International inbound tourists in Ukraine, Romania and Bulgaria. Source: complied by the authors according to World Bank (2017)

tourist flow in this area, however, the ecological factor isn't the first priority in choosing a tourist destination. There is another situation on the coastal area of the Black Sea Region. One of the indicators of the quality of the recreational area near the reservoirs is the state and purity of water resources. Therefore, we can observe a significant reduction of the attractiveness of recreational areas in the port area, where there is a permanent impact of navigation on the quality of water in the coastal area (Athanasoglou, 2014).

As we can see in Figure 6, the flow of tourists has been significantly decreased in Ukraine since 2014, which correlates with the beginning of the political and economic instability of the country. While in the territory of Bulgaria and Romania there is a steady increase in the number of the arrived tourists, which also has a positive effect on the GDP of the countries. One of the most famous recreational areas in Ukraine is Odessa, which is washed by the Black Sea.

Let's analyse the situation in Odessa Region of Ukraine (Fig. 7), characterised by the large coastal zone, the sea and developed infrastructure

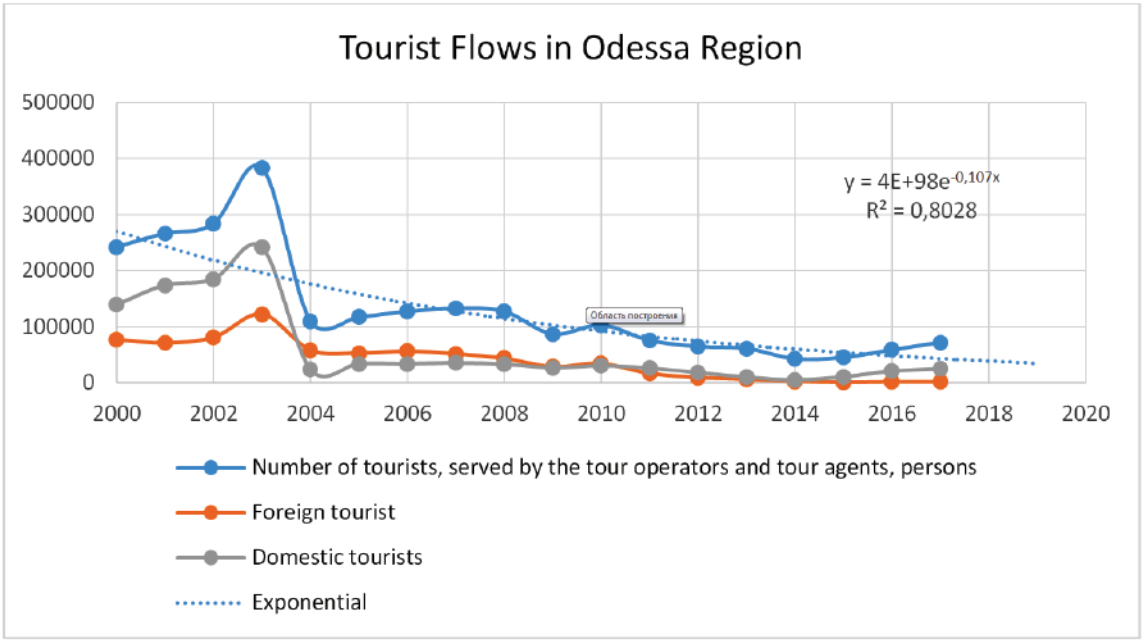

Fig. 7. Tourist Flows in Odessa Region in the time interval. Source: complied by the authors according to Knoema (Knoema, 2018)

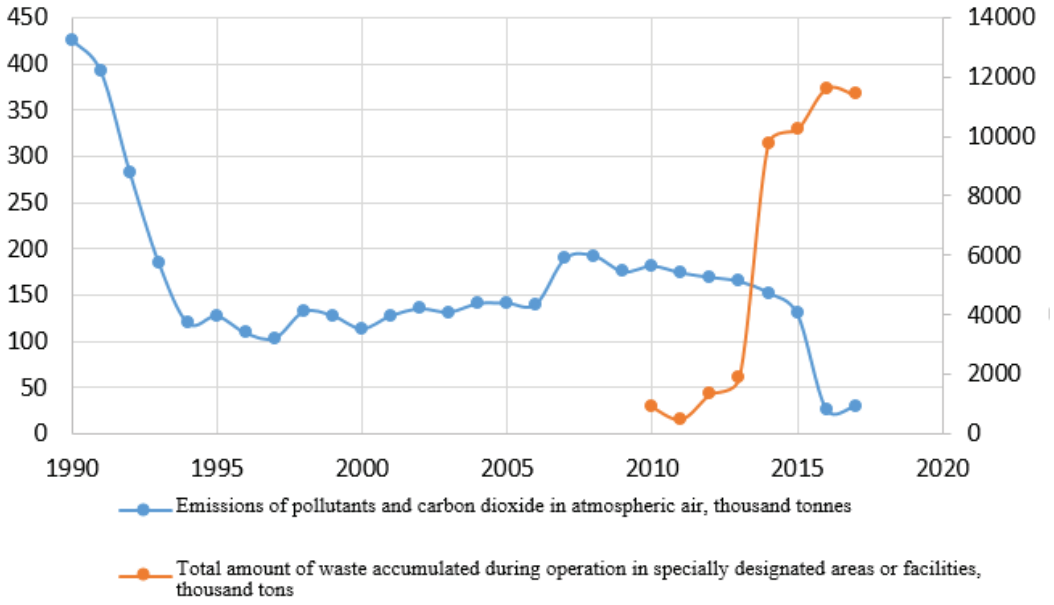

Fig. 8. Dynamics of Pollutant Emissions and Number of the Accumulated Waste in Odessa Region
Source: complied by the authors according to State statistics service of Ukraine (2018)

for recreation and sanatorium rehabilitation. As we can see from Figure 7, the data of tourist flows correlate with the economic situation in Ukraine. Therefore, it was a sharp decline in 2014, a year of political changes and economic instability, but then the situation was getting better and the number of tourists was increasing to the level of 2011, which was also because of the decrease of tourist traffic in the Crimea. Another factor influencing tourist traffic in Odessa Region is the price policy. Choosing the place of the rest, tourists often prefer to spend time in such countries as Turkey and Bulgaria, which are the alternatives due to environmental and purpose factors, in these countries tourism infrastructure is better established. Also in Odessa Region there are many industries which influence to the ecological state and the problem of the utilization isn't solved.

As we see from Fig. 8, in case of the pollutants decreasing which are falling into the atmosphere, the amount of the accumulated wastes which are falling into the waste landfills is increased and together with filtrate poison the soils, ground waters and the Black Sea water area.

Therefore, according to the State Statistics Service of Ukraine (2018), in 2018 there are 617 landfill in Odessa Region with the total area of 952.39 hectares. Another problem is the liquid household waste that enters the sea by removing the pipeline to a depth of more than 5 meters. In Ukraine there is old filtering equipment and the waste is almost non-filtered, thus worsening the Black Sea water area. This creates additional risks for living organisms and adversely affects the health of tourists and population. Thus, in Odessa Region there was an incidence of intestinal infections, skin diseases and respiratory tract. According to this decision we can conclude that there is the negative impact of the industrial production and accumulated waste and general anthropogenic load on the recreational zones of Ukraine and the reduction of their tourism potential (Koval, Mikhno, 2019). Pollution of the Black Sea water area leads to deterioration of the ecological situation in other countries bordering Ukraine. This reduces the attractiveness of the regions for the development of seaside rest. However, these countries have a flexible price policy, thereby increasing tourist flows.

Let compare the number of tourists and anthropogenic impact on the coastal areas of the Black Sea region in Ukraine, Bulgaria and Romania.

The eastern part of Bulgaria runs along the Black Sea coast and has a length of 394 km, while the length of the Romanian coastline is 256 km and Ukraine is 1006 km (Fig. 8) (Suciu, 2016).

As we see from Fig. 9, Ukraine has the largest percentage of buried waste (95%), while in Bulgaria it is the smallest (64%). This shows both the higher cultural and economic level of the country, and the less littered territory and the best environmental status. In 2017, the number of tourists in Ukraine was 14.2 million people, in the territory of Bulgaria - 8.9 million people, in Romania - 2.8 million people, so we can notice that the coast of Romania (analysing the number of vacationers on 1 sq. km) is most affected by anthropogenic influence because of the availability

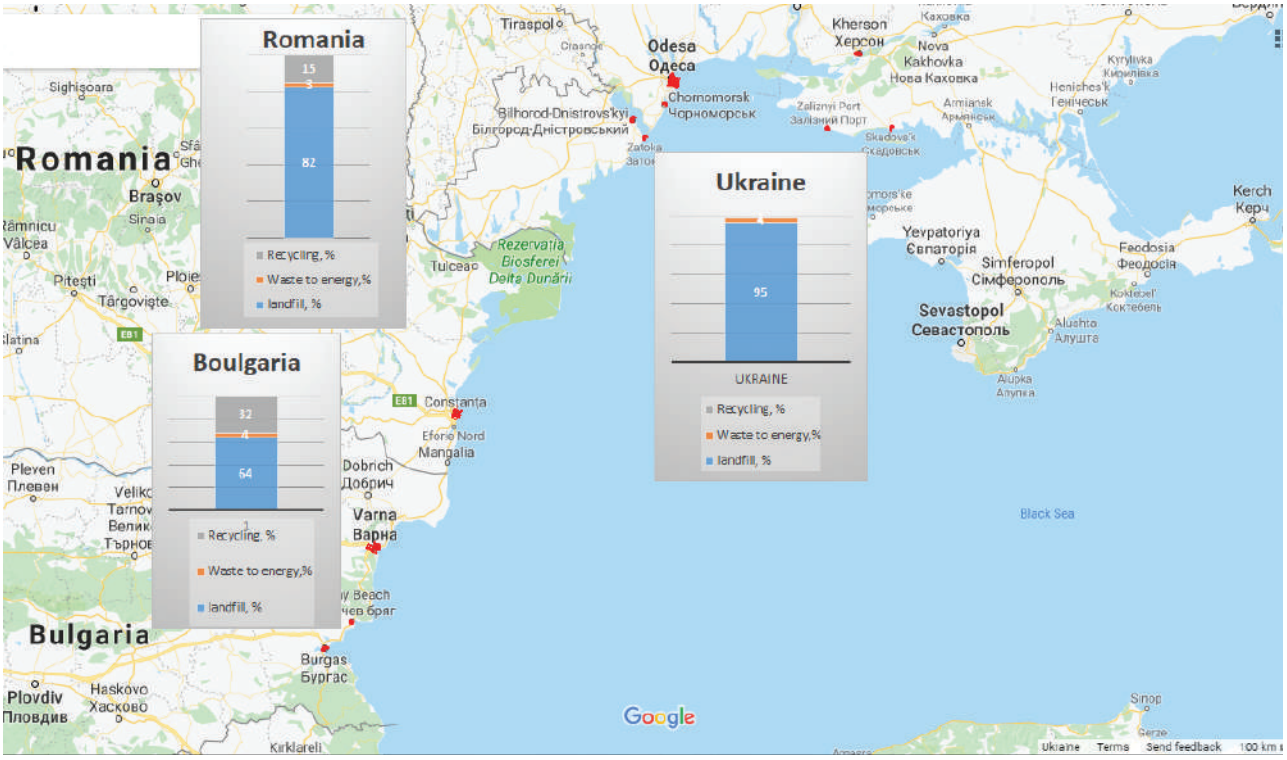

Fig. 9. Coastal areas of the Black Sea region of Ukraine, Bulgaria and Romania according to Google earth and data on waste management. Source: complied by the authors

of zones for rest and has limited capacity to restore the environment because of the poorly developed tourism infrastructure, the government's reluctance to invest in environmental protection and deterioration of the water of the Danube, affecting the areas of the Black Sea.

The tourism in Bulgaria is more attractive for vacationers due to the developed infrastructure and advertising campaigns. However, the activity of large industrial enterprises negatively affects on the environment and worsens the water resources.

Ukraine is a leader in the pollution of the water area with sewage and pollution of the air. A special feature is ignoring the legislation and ecological norms by lots of entrepreneurs in order to achieve maximum profits due to deterioration of the environment. Analysing the indicators of the environmental pollution, the development of tourism infrastructure, we can underline that Bulgaria is more attractive for tourism and has larger tourist flows in looking for sea recreation, while Ukraine is the worst alternative and has the most polluted water area with sewage and general pollution because the operation of large industrial enterprises.

Let see the tourist traffic in the big cities on the examples of Odessa, Varna and Constanta, they are the important transport hub, cities with the population density, developed industries and place for recreation with a lot of sanatoriums.

As we see from the Table 1, the largest concentration of tourists is observed in Odessa, which is the largest city among the exploring cities. A main feature of this city is the construction of a large number of recreation areas and hotels. However, if we analyses the quality of service and environmental characteristics, the leader among the tourists will be the city of Varna, which has the lowest environmental impact and has a less powerful port. In Constanta, a powerful port was built, which is one of the largest elements of water pollution, but it contributes to the increasing of the tourist flow through the operation of the marine transport hub. The analysis of the data stated in Table 1 showed that Odessa has the greatest environmental impact, as a result of a change in the natural landscape because of the construction of a recreational zone, and due to the general pollution of the territories and the accumulation of waste that merge into the reservoir or that are buried.

The largest tourists' traffic in Odessa is due to the decrease of recreational areas in Ukraine through the Autonomous Republic of Crimea Annexium, the development Odessa as the sea hub and cultural centre, relatively inexpensive rest with the minimum costs for transfer for Ukrainians and the propositions from the service sellers.

Actuality of environmental research about Odessa Region proved the needs of the need for the implementation of a comprehensive system

Table 1. Comparative characteristics of the cities of Black sea regions

Indices	Odessa	Varna	Constanta
Permanently residing population, persons	1,093,120	335,177	297,503
Number of vacationers per year, thousand persons	5,700	966	874.7
Port cargo turnover per year, million tonnes	24,163	10	51.8

Source: complied by the authors according to (NISR, 2018; NSIRB, 2018; State Statistics Service of Ukraine, 2018)

conception, which includes rational tourism and recreational nature using. If the tourist industry became strengthened economically, guests will be at least 5 million a year, however, within the ecologically safe limit must be no more than 24 million tourists a year. And the businessman must obey the Ukrainian legislation and the recreation area should be given a special status, which is more strictly conducted monitoring, environmental and economic assessment, inventory of resources suitable for tourism, their certification, registration, definition of the legal regime of tourist resources for compliance with regulatory requirements. It is necessary to make a modernization and reconstruction of the material and technical base of the tourist infrastructure objects more often. And it would be made according to all environmental standards, increasing the number of parks, beaches, cultural institutions and improving these territories.

The index of water pollution for all list of components, including pH of hydrogen, biological oxygen consumption and dissolved oxygen was calculate. The C(i)/maximum permissible concentration (i) will find the actual concentrations to the MPC and the result list will be sorted. The IRS is calculated strictly for the six indicators which have the highest values of the reduced concentrations, despite of whether they exceed the MPCs or don't. In exploring regions the biggest anomaly was in Odessa, in selected samples of water exceeded the maximum permissible concentrations of suspended matter, hydrogen sulfide and iron, as well as reduced oxygen concentrations example. It should be noted, that in all exploring points there was an increase in the number of sulfates and a decrease of the oxygen content compared with the control point (deserted coast at a distance of 5 km away from Varna).

A large number of tourists enhances the problem of human waste and increases the speed of the emergence of illegal landfills. Despite EU's requirements for sorting and recycling of garbage, only 1% of waste is recycled in the country. Because of using the old methods of waste and making of accumulated garbage masses and drainage in liquid wastewater reservoirs for many years, the risk of morbidity of the population in the territory of the Odessa region, including tourists, is increasing. Other recreational areas on the Black Sea coast are also affected. If you use the multiplier of the standard landfill area, then the landfill impact factor needs to be increased by 84 times (Skripnik, 2014). That is, when the liquid household waste is poured into the reservoir, the area of influence must be increased by 84 times.

In many places of rest (sanatoriums, boarding houses) untreated household wastewater accumulates in cesspools in volumes exceeding 1 m^3 / day and is taken to landfills of liquid household waste located in the coastal protective strip or these areas are equipped with pipelines that discharge waste directly in the sea. Places of discharge of liquid waste according to sanitary and epidemiological standards should be located at a distance of at least 4 km from places of accumulation of people or living quarters. However, in the Odessa region there is a constant storm of untreated waste in the water area at a depth of about 16 m and a distance of 150 m or less from the beach (Word and Case: Analytical Portal, 2018). If to take into account these data, the water area within a radius of 336 km is poisonous. In its waters may be increasing of salts, heavy metals, and other poisonous elements. There is a proliferation of bacteria and other dangerous microorganisms that can cause morbidity and epidemics. Flora and fauna of the Black Sea is changing and it can lead to the disappearance of certain species of living organisms and increase the number of others, and in the future - to the ecological catastrophe.

Prevention of environmental pollution by human waste is a serious problem, and the current practice of sustainable development in Ukraine is limited. There is a need for a radical change in the

behavioral principles of all participants, and for this it is necessary to focus on increasing environmental responsibility (Popova et al., 2019). Therefore, it is necessary to fully understand the long-term benefits of avoiding of human waste for the environment and economy (Sushchenko, 2018).

According to the results of the research it can be argued that the coastal area of Ukraine and Romania is clogged, and taking into account the constant garbage and litters not only domestic but also industrial waste, the being of large landfills that pollute rivers flowing into the sea and landfills along the coast with filtrate from which comes directly into the waters of the Black Sea, the recreational areas are high-risk areas and, instead of the health-improving effect, may be the cause of diseases of tourists.

Conclusions. In nowadays the attractiveness of the service sector is increasing in Ukraine and all over the world. Tourism, as one of the key elements of society's life, has a major impact on such important sectors of the economy as transport and communications, building, agriculture, production of consumer goods, and others and increases the country's GDP. However, the impact on the natural environment, landscapes, and anthropogenic impact on the ecosystem are increasing.

Choosing a place for rest and vacation there are various factors of influence, one of which is the ecological component of the recreational zone. Often untapped and protected areas are becoming more popular for recreation than well-known equipped places and territories. Very often nature isn't ready to self-regeneration, and according the Pigou's theory, negatively externals are above profits. An analysis of the country's environmental performance indicator has shown that tourism traffic is higher in countries with a higher EPI than in countries where the environmental state and compliance with environmental legislation are lower.

In Ukraine, main problems are the depletion of territories and low compliance with environmental legislation. On the basis of a comprehensive analysis of the sphere of processing and utilization of human waste, it has been discovered that because of the incompletion of the institutional transformations, in Ukraine environmentally hazardous and economically unjustified method of dealing with solid household waste is operating since the years of planned economy. That is why human waste was storing and drainage into the reservoir, which affects the state areas near disposal places. It is based on the false assumption that the natural environment is capable of absorbing both industrial and domestic waste.

Analyzing the recreation areas in the Black Sea region, we have seen that nature can't be restored independently under anthropogenic stress. The Odessa Region, as a place of recreation and tourist accumulation, is a high-risk area, and the present state of waste management affects the Black Sea water area at a distance of 336 km from waste points, and with a constant accumulation of these areas, this territory becomes considerably higher. Analyzing the places of recreation, it is concluded that Varna is the best alternative for the recreation on the Black Sea coast and has a lower anthropogenic impact than the city of Odessa.

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Analysis of the recreational resources of Kaniv in the context of the programme of development of Ukrainian small-cities

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Abstract. The purpose of the article is to highlight the problem of using the potential of local territory in the processes of promoting local uniqueness as a consumer product. This study aimed at analysis and appraisal of the recreational resources of Kaniv for the organization of recreational activities in the planning strategies of the city as a recreational and tourist center. The study of the entire set of recreational resources of the city resulted in a constructive analysis and evaluation of the recreational benefits of the city's resources. In the course of the survey, the directions of recreational environmental management in the city were determined in accordance with the programme of development of small Ukrainian cities. The analysis and assessment of the territory's resources was conducted using integrated methodologies of studying recreational assets that take into account the evaluation methods of medical geography, recreology etc. Our study found that geomorphological, climatic, water, biotic, and landscape recreational natural resources are significant for the organization of recreational activity in the city and which, according to the estimation of recreational favourability, are highly conducive and convenient for both winter and summer recreation. A number of indicators of natural resources are of high value for the treatment and prevention of a wide range of diseases, including problems with respiratory, cardiovascular, nervous systems. The development of recreation and tourism in the city is also influenced by the existing historical and cultural resources, which include a whole set of archaeological, architectural and historical monuments, ethnographic features and crafts, museums and exhibitions, places and areas of significant events, places of life and creativity for prominent personalities, heroes and figures, etc. The socioeconomic resources and infrastructure of the city have a significant impact on the functioning of the recreational affairs, such as the state of the existing and prospective territorial organization, transport accessibility and level of its development, the public service and its condition (food establishments, residence, etc.). Nowadays, Kaniv is characterized by partly lower indicators of socio-economic development, business activity and, at the same time, enjoys a powerful natural, recreational and tourist, historical and cultural potential. Development of recreational and tourist activity in the city should be considered as a tool for increasing economic indicators (employment, business activity and growth of its financial indicators) and improvement of demographic indicators (reduction of labour migration, etc.), etc. The natural and cultural heritage of Kaniv is a source of socio-economic and human development through the integration of cultural monuments into the national tourist network. This can be achieved through the creation of new museum programmes, the development of a network of establishments based on authentic cuisine, traditional interiors, etc. It can further be promoted through creation of a network of ecological trails and routes which give access to the area's unique natural ecosystems. Recreation and tourist activity can also be encouraged through popularization of environmental affairs, creation of programmes for development of the resort business, programmes of family recreation, development of different types of water, hiking, educational (culture, events, research, etc.) and eco-tourism, and the development of programmes and events in the field of sport fishing and hunting.

Keywords: development of small-cities, recreational resources, recreational favourability, recreational activity

Аналіз рекреаційних ресурсів міста Канева в контексті програми розвитку малих міст України

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Анотація. В статті розглядається проблема ревіталізації малих міст України через використання місцевої унікальності та ідентичності міста при створенні іміджу в процесах просування локальної індивідуальності як споживчого продукту. Сучасний підхід в плануванні місцевого розвитку будується на розумінні природних, історико-культурних, етнографічних, туристичних

ресурсів як суми економічних активів, що здатна зробити прямий та опосередкований внесок в економічний розвиток малих міст. Мета статті обгрунтовується підходами сталого природокористування в містах, як інструменту підвищення показників соціально-економічного та людського розвитку, і, як результат, покращення якості та комфортності життя містян. Метою дослідження є конструктивний аналіз та оцінка рекреаційних ресурсів території міста Канева та його околиць для забезпечення формування програм організації та розвитку рекреаційної та туристської діяльності і стратегічного планування розвитку міста Канева, як рекреаційного та туристичного центру. В ході дослідження виявлено та проаналізовано потенційну сукупність рекреаційних ресурсів міста та оцінено їх рекреаційну сприятливість, з'ясовано напрямки існуючої рекреаційної діяльності і встановлено перспективи рекреаційного природокористування. Аналіз та оцінка рекреаційних ресурсів міста здійснювалася із використанням способів комплексних методик вивчення рекреаційної сприятливості, що застосовуються в медичній географії та рекреалогії. Результати дослідження вказують на невисокий соціально-економічний розвиток, незначні показники ділової активності попри потужний природний, рекреаційно-туристичний, історико-культурний потенціал міста Канева. Природна та культурна спадщина міста Канева є фундаментом соціально-економічного і людського розвитку через інтеграцію об'єктів та пам'яток в національну туристичну мережу, через інновацію музейних програм, створення мережі екологічних маршрутів, створення програм для розвитку курортної справи, програм сімейного відпочинку та інших видів діяльності.

Ключові слова: *розвиток малих міст, рекреаційні ресурси, рекреаційна сприятливість, рекреаційна діяльність*

Introduction. Analysis of the current world trends of development of urban areas, small towns in particular, involves features of their geographical, environmental, social functioning, planning organization and the impact of urban settlements on the surrounding areas and coverage of issues of implementation of world practice in strategic management of tourism development in the regions. The importance of small and medium-sized cities in regions as centers of significant human capital, balanced management, economic potential, as business environment, cultural, recreational and tourist centers has been highlighted in the research publications of local and foreign authors such as Nudelman V., Boyko-Boychuk O., Edans Ch., Ledri R., Dolishniy M., Mezentsev K. and Mezentseva N., Denysenko O., Dronova O., Nekos A., Mal'ska M. and others.

The study of the recreational resources and tourist potential of territories, complex assessments of favourable recreational conditions of territories, the issue of quality and significance of recreational potential as a basis for the development of recreational and touristic activities is the subject of the research and publications of Preobrazhensky V., Mukhina L., Danilova N., Fomenko N., Lyubitseva O., Smal' I., Stafiychuk V., Baidyk O., Arion O., Kochetkova I., Mykhailenko N., Kulinich M., Holubychna S., Danyl'chuk G., Tsarik L., Chernyuk G. and other authors.

The modern approach to socio-economic planning of local development, which is used nowadays in the processes of revitalization of towns in Ukraine, is based on the understanding of resources (natural, historical, cultural, ethnographic, tourism) as the sum of economic assets that can make a direct and indirect contribution to the economic development of towns (Boyko-Boychuk, 2010., Frenkel', 2018). The main goal of this approach is to create and implement a "creative product" that is considered as the generation and transformation of creative ideas (using human, cultural, tourism and other resources) into economic potential and consumer product. This approach in modern urbanization processes and socio-economic rebirth of the urban environment uses the local identity of the city, its urban culture, in the creation of a brand in the processes of promoting the local identity as a consumer product.

In Kaniv traditional approaches to forming the directions of urban development (both territorial and socio-economic) and the difficult economic conditions of the late 20th and early 21st centuries have led to the loss of status of a multifunctional industrial city and, despite its rich resource and human potential, the city entered the stages of stagnation and cultural decline.

Natural and cultural heritage give potential for the revival of territories and has strategic importance in promoting sustainable and integrated development of regions and cities. Such development would benefit from the use of such approaches as branding of the city and region, the creation of a special image (cultural, tourism) of the territory, analysis of consumer needs, the development of sustainable and innovative forms of recreation and tourism. The development of a unique and innovative tourism product, creating jobs in the service sector, should contribute to capitalization by investing in tourism services, and attracting various types of resources (human, material, natural, etc.) in new directions of urban development. (Frenkel, 2018).

The aim of this article is justified by the processes of reforming the territorial development of the regions of Ukraine. The concept of sustainable environmental management in cities and the programme of the revival of towns of Ukraine is a tool for increasing the indicators of socio-economic and human development, business activity and, as a result, improvement of the quality of life and

comfort for the citizens. Therefore, a comprehensive analysis with the definition and partial assessment of the recreational resources of the area of research is the purpose of this study , which aims to determine new directions of organization of recreational and tourism activities in planning the strategies of the development of Kaniv, as both a recreational and a tourist center. To achieve the goal set in the research, the following basic tasks were set: to identify the whole potential of recreational resources of the town. To analyze and evaluate the recreational benefits of the town's resources, to ascertain the direction of the existing recreational activities of the city and its outskirts and to establish the perspectives of the recreational environment of Kaniv in accordance with the programme of development of Ukrainian towns.

Material and methods of research. The object of this study is the entire set of recreational resources which are present in the territory of Kaniv and its outskirts. The study is based on the understanding of recreational resources as phenomena and objects of the natural or anthropogenic environment and management system, which have a number of significant properties for recreation, and which can be used in the organization of various types of recreational activities and as a method of recovery of the health and working capacity of the population. These properties include natural and cultural uniqueness, which is a component of aesthetic attractiveness, recreational value and healing qualities of the objects. The decisive feature is that the quality, diversity and correlation of the recreational resources of the town and the region allows recreational activities of varying lengths and independently of seasons to be developed daily, weekly and year-round. In general, in recreation studies, there are three groups of recreational resources: natural, historical and cultural, socio-economic.

The most significant recreational natural resources of Kaniv and its outskirts are geological and geomorphological, climatic, water, biotic (forest, faunistic), and landscape resources. Natural recreational resources also include objects and territories of the Nature Reserve Fund. In addition to natural resources for the development of recreation and tourism in the town, there are also significant historical and cultural resources, such as archaeological, architectural and historical monuments, museums and exhibitions, ethnographic features and crafts, places of residence and creations of prominent personalities, heroes and figures, etc.

The socioeconomic resources and infrastructure of the city make a significant impact on the development and, most importantly, the functioning of recreational affairs. Socio-economic tourism resources include geographical location and modern territorial organization, transport accessibility and level of its development, the sphere of service of the population and its state (nutrition, hospitality, etc.), labour resources, demographic conditions and a number of others.

An analysis of the favourable conditions of the territory in this study is carried out in accordance with the approaches of socio-economic planning of local development and revitalization of Ukrainian towns, based on the concept of sustainable use of nature. Analysis and evaluation of recreational resources of the territory is carried out using complex methods of studying recreational favourability, which are used in recreational, medical and geographical research. Comprehensive assessment of the recreational enrichment of the available resources of the territory of the city was based on open data of existing open source information. We used the resources of the Hydrometeorological Service of Ukraine and the Kaniv Meteorological Station, resources of State Research-and-Production Enterprise "Geoinform of Ukraine", resources of the State Service of Statistics of Ukraine, resources of the Ministry of Ecology and Natural Resources of Ukraine, etc.

The results and their analysis. Kaniv has unique resources for development and socio-economic rebirth. Under the existing typological scheme, Kaniv can be classified as a city with significant natural, historical-cultural, recreational and health potential. According to the specifics of the employment of the population in various spheres of economic activity, Kaniv counts as an economic center of local importance, the center providing social-cultural, communal and other services and, at the same time, is a historical-cultural and tourist center.

Nowadays, Kaniv is characterized by slightly lower indicators of socio-economic development, business activity, though, at the same time, it has a powerful natural, recreational and tourist, historical and cultural potential. The development of recreational and tourist activities in the city should be considered as a tool for improving economic indicators (employment, business activity, growth of financial indicators of business activity), improvement of demographic indicators (reduction of labour migration), etc. The natural and cultural heritage of Kaniv is a source of socio-economic and human development through the integration of cultural monuments into the national tourist network. This potential can be realized through the creation of new image museum programmes, the development of a network of hospitality facilities

offering authentic cuisine, traditional interiors, etc. and establishment of a network of ecological trails and routes which introduce the visitor to the area's unique natural ecosystems. Important measures in this respect could be popularization of nature protection activities, creation of programmes for the development of resort business, programmes of family holidays, development of different types of water, hiking, educational activities (culture, events, etc.), eco-tourism, and the development of programmes and events in the field of sport fishing and hunting.

Therefore, a clear resource orientation determines the recreational and tourist activities of Kaniv. The presence and high quality of recreational resources are the basis and guarantee of recreational nature use of the city and its outskirts, and should determine its recreational specialization.

The terrain and geological structure of the city's territory is a leading factor in the formation of unique natural conditions that have developed in the city and its outskirts, determining the specifics of urban planning of territories and the organization of nature use within its boundaries. The study and analysis of the geological and geomorphological structure is an important point in clarifying the recreational value of the territory, because the relief and geological structure determine the landscape diversity of the territory, affecting a number of significant recreational, tourist and technological indicators. The analysis and assessment of the recreational value of the territory requires detailed study, description and fixation of the characteristics of its geological and geomorphological structure. Assessment of the suitability of terrain resources for recreation and development of the directions of its use should take into account the likely negative effects of the terrain and the quality of geological sediments on recreational or tourist activities.

The results of the study indicate that a significant part of the city's territory is located within the Kaniv dislocations, which are hilly lowlands with absolute altitudes of 200-220m (max. 255m) with a highly developed gully-arroyo network. The depth of dismemberment of the dislocated area sometimes exceeds 100 m, so it appears mountainous. Significant amplitudes of absolute markings (up to 100-120 m), sediments and storm rainfall determine the development of erosion processes, resulting in a dense and extensive gully-arroyo network (0.4 km/ km2). In the limits of the hilly areas of the city, in addition to erosion, gravitational processes are also observed, most often in the form of landslides. All shifts within the limits of the Kaniv Mountains are divided according to the age of formation into the ancient Anthropocene and modern Holocene (Moroz, 1971, Kudelja, 1971, Palienko, 1971). For example, the economic zone of the Kaniv Nature Reserve, which is situated within the bounds of the city, is located on a landslide pseudo-terrace of the late Anthropocene period, which is penetrated by the deep gullies Bilyashivsky 1 and 2, Rotten Ravine (Hnyla Balka) and others. The anthropogenic shifts are confined to the steep right bank of the Dnieper, with a stepped structure and are immovable (it is possible to observe on Mariyina Mountain, the Great Settlement, etc.). Modern shifts occur most often in the systems of gullies, forming semi-circles with large angles of inclination of the moving surface of the displacement (annual movement from 0.5 to 1.0 m) (Grubrin, 1968, Moroz, 1971, Kudelja, 1968, 1971, Palienko, 1968, 1971).

Significant heights, strong surface erosion, evidence of natural geodynamic processes in the city's hilly area, despite the environmental and engineering negativity of these physical and geographical phenomena, in combination with plant diversity, determine the significant degree of diversity of the territory's landscapes. The expressive physiognomy explains the high degree of aesthetics of the landscapes of the hilly part of Kaniv. The use of geological attractions as objects of excursion display in geotourism and objects of interest in scientific tourism explains the increased attention paid to geological resources.

The primary terrain of the Kaniv Mountains, formed by tectonic movements in the Mesozoic, has not survived through widely developed erosion processes. In the modern terrain formed as a result of neotectonic movements there is a phenomenon characteristic of the Kaniv mountains – overlapping scales structures , which is associated with structural nonconformities in the places of discontinuous deformations accompanied by the imposition of ancient sediments of the Paleogene (scale type structures), Cretaceous, Jurassic on modern Anthropocene (Moroz, 1971, Kudelja, 1971, Palienko, 1971). At the same time, , the richness of the lithological composition of sedimentary rocks within the limits of the Kaniv mountains is connected with the folded deformations, which is the lithological basis for the formation of the landscape diversity of the hilly part of the city. Basically, these are Anthropocene sediments loess and loams, fluvioglacial sands, moraine loams, and sandstones with boulders of crystalline rocks , which are huge (on average 10-15 m), but often interrupted, especially on the watershed ridges and slopes of

the ridge of the southern exposure, the eluvium of the ancient rocks of gravel-sandy composition (Paleogene, Cretaceous, Jurassic).

Lithologic layers and the outcropping to the surface of ancient rocks clarify the geological history of the development of landscapes through the existing paleobotanical, paleozoological artifacts. Exposure of the slopes with the general elevation of the mountainous areas simultaneously has a significant impact on the microclimatic differentiation within the limits of the Kaniv Mountains (recreational value), simultaneously determining the variety of plant species and the spatial and structural wealth of the landscape complexes of the mountainous part. Undoubtedly, geological and geomorphological features influence the optimization and prospects for housing construction, improvement of conditions of rest, and for creation of a comfortable environment, etc.

On the ranges of the Kaniv Mountains, there are natural observation decks which give spectacular views of the surrounding terrain. From the top of the range, there is an overview on the hill's sheltered terrace (north) and mountainous forest-moraine plain (south). From the observation decks of such mountains as Plastunka, the Great Settlement, Chernecha, Lysa, Pylypenkova, Moskovka and other mountains can be seen numerous oxbow lakes, distributaries, straits, the floodplain islands Shelestiv and Cruhlik and the streambed of the Dnieper, which is characterized by intensive steamed processes. A panorama is opened on the picturesque left-bank landscapes of the terraces and wide floodplain of the Dnieper.

The Dnieper River valley within Kaniv and its surroundings is a relatively lower alluvial plain. Four fluvial terraces, high and low floodplain terraces are distinguishable in the structure of the Dnieper Valley. The first floodplain or sandy terrace is manifested as broad strands along the valley and islands in the floodplain, composed of ancient alluvial sands that are covered with pine forests. The sandy terrace is elevated towards the flood plain at ≈8-16 m, absolute marks in the relief reach 120 m. The surface of the pine terraces the Dnieper is a low, hilly plain with dunes and sands. Individual dunes reach the height of 20 m. Deserted areas of sands and dunes acquire mobility. As a result, the nature and intensity of soil nutrition, in contrast to the flood plain of the river valleys, is significantly changing. The level of groundwater is greatly reduced and in the conditions of general lift of the surface background, automorphic soils are formed: sod-podzolic and podzolic. The lifted mountainous terrain and, especially, the lithology of the sediments also condition microclimatic differentiation within the limits of the pinewood terraces. The vegetation of the pinewood terraces is predominantly composed of psammophytic forest formations, formed by plantations of pine and common admixture of broad-leaved species: common oak, black locust (*Robinia pseudoacacia*), silver birch, common pear, etc. Drought-tolerant cereal grasses or , in conditions of sufficient moisture, the flora of vegetative groupings with moss cover exemplified by fork mosses, haircap moss, etc represents the herbaceous cover on the pinewood terraces. In addition, within the pinewood terraces, the lithological composition of sediments is clearly observed in the nature of the vegetation and, accordingly, the characteristics of the soils. Sandy sediments determine the thermal, water and other physical and chemical properties of the soils of the pinewood terraces, which will directly affect the vegetation. Thus, in the watersheds of the dunes and the slopes of the southern exposure, treeless open areas form xerophytic conditions, which result in the spread of Scots pine practically free of admixtures of other tree species and sharp-leaf willow, and the grass surface consists of dry grasses and spurges with numerous lichens. On the slopes of the dunes of the northern exposition and on the interdunal and lowered areas, the conditions of growth vary in the direction of mesophilicity. Thus, tree layer and undergrowth, in addition to the Scots pine, is represented by broad-leaved species, and in the grass surface there is a greater variety of grasses and cereals, mosses and ground pines (Kupach, 2017, Dem'janenko, 2017).

Within the floodplain of the Dnipro River, the following mesostructures are distinguished: the levees, the high floodplain areas, the oxbow lakes' depressions, and the lower terraced area. Relatively elevated areas composed of sandy sediments of large fractions represent the levees' part of the floodplain. As a result, in the levees' floodplain a xerophyllous forb community with features of steppe species is formed, rather rarefied and unproductive, which causes the development of poor soils. A characteristic species of the levees' floodplain is desert false indigo, which grows densely and forms shrubbery. A variety of forms of microrelief – low ridges, hills, swales, and so on characterizes the central floodplain. The central part of the floodplain consists of, unlike the levee part, sandy sediments of small and dusty fractions, which characterizes the soils as fresh or wet. Bean family plants and cereal flora form in conditions of sufficient moisture; vegetation is rich and highly productive. The terrace near the floodplain and the oxbow lakes' depression, due to the drainage of atmospheric, groundwater and stagnant water, is often marshy. The

lithological composition of the sediments is mostly dusty and muddy, which also causes the development of water retention regime in soils - that is, the formation of waterlogging. In the over-humidified conditions, moisture-loving vegetation of large cereals and carex in alternation with forests of aspen and alder is characteristic.

The geological structure and terrain of the territory is a leading natural factor in the formation of the rich landscape diversity and contributes to enhancing the attractiveness and aesthetic properties of the landscapes of Kaniv. Landscapes of broadleaf forest, mixed-forest, meadow-steppe, steppe, meadow and swamp type represents the landscape structure of the city and its outskirts (Kupach T., 2017, Kupach D., 2017, Dem'janenko, 2017).

The whole set of characteristics of the terrain, geological sediments, vegetation surface, which include amplitudes of heights, the frequency of slopes, the intensity of the dismemberment of the terrain, changes in the exposure and steepness of the slopes, the quality of plantings and landscape diversity affects the formation of landscapes, physiognomy, diversity, contrast, and determines the tourist and recreational favourability of the territory. Table 1 shows the evaluation criteria for the favourable geological and geomorphological and landscape resources for tourist and recreational activities adopted in assessments of recreational favourability (Preobrajgenskij, 1975, Muhina, 1975, Kazanskaja, 1975, Vedenin, 1975). The most commonly used is the 5-point rating scale: 1 - relatively favourable, 2 - less favourable, 3 - favourable, 4 - significantly favourable, 5 - most favourable.

The climatic and hydrological resources of the territory have a significant influence on the recreational attractiveness and suitability for different types of recreation, especially in the warm period. The significant amount of sunshine and temperate climate is decisive for the development of recreational use of nature within the city and its outskirts. On average, in Kaniv district, the duration of sunshine annually exceeds 1710 hours, which is closer to the indicators of the Black Sea coast (Shherban', 1962). The maximum values of the duration of sunshine are from May to August (≈ 700 hours), and the minimum are in December (≈30 hours), according to the Climatic Cadaster of Ukraine (2006). In Kaniv district, there is also a good number of sunny days is autumn.

Figure 1 shows data on the average actual sunlight duration and the average number of days without sun for each month of the year, which was determined for a long period of observations (according to the Kaniv Meteorological Station). Thus, it can be said that the period suitable for such activities as recreation on the water, treatment and prevention of diseases, active tourism, in particular, hiking, cycling, water, etc., is quite lengthy and includes 7 months: from April to November.

For the autumn-winter season, the formation of misty weather is characteristic of Kaniv and Kremenchug reservoirs. In autumn , fogs lend a picturesque quality (a significant parameter in the ecological and aesthetic assessment of the suitability of the territory) to the flood landscapes along the valley with lake basins, old oxbow lakes and landscaped curtain walls of the mountainous-forested part of the city.

Figure 2 shows the average duration of misty weather for certain months, as well as for the cold and warm periods.

Latitudinal position, duration of sunshine, and the type of vegetation cover within Kaniv and its outskirts strongly influences the formation of a temperature-favourable regime for recreation. The amount of solar radiation per square centimeter of surface annually reaches about 100 kilocalories. However, the distribution and assimilation on the earth's surface of this heat within the city and its outskirts is extremely uneven and is due to the specific nature of the sediments, terrain and vegetation (Shherban' 1962).

For example, in the hornbeam forest of the mountainous part of the Kaniv Nature Reserve, only 10% of the total solar radiation reaches the surface, and in the pine forests of the terraces of the Dnipro River the total radiation dose varies (depending on the

Table 1. Summary of the results of the degree's assessment of recreational favourability of geological-geomorphological and landscape resources for recreational activities in Kaniv

evaluation criterion	hypsometric indices	horizontal dismemberment	vertical dismemberment	visibility	variety
score	3	3	4	4	4
the degree of recreational favourability	favourable	favorable	significantly favourable	significantly favourable	significantly favourable

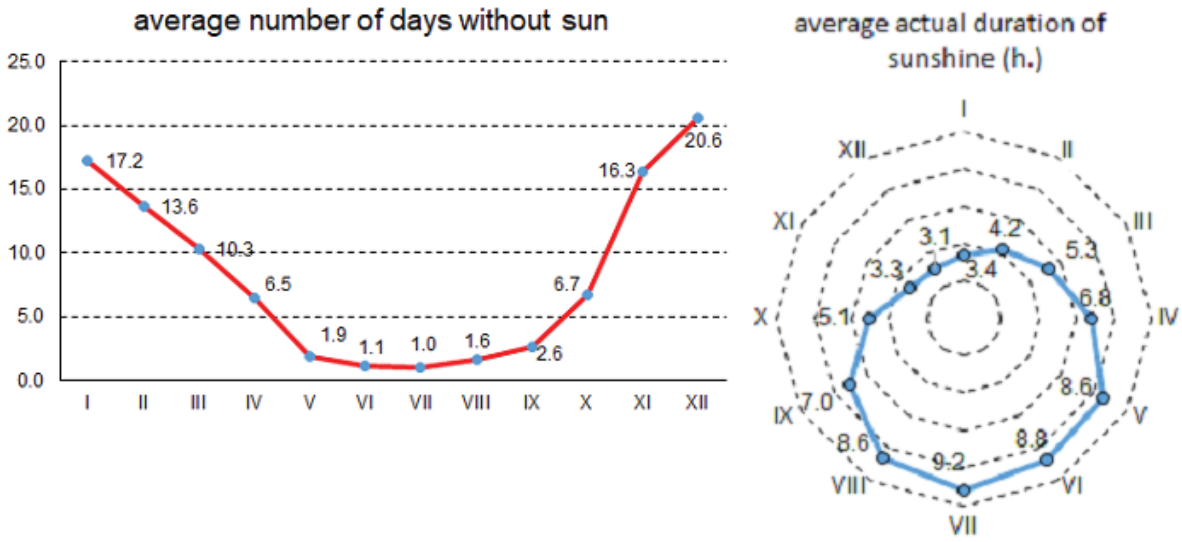

Fig. 1. Diagrams of the average actual duration of sunshine and the number of days without sunshine in the meteorological station "Kaniv» in the years of observations in the period from 1960 to 2010.

time of day) from 40 to 75%.

The nature of the surface also significantly influences the re-distribution of heat in the studied region. Therefore, the absorption of heat will vary depending on the steepness and exposure of the slopes of the Kaniv Mountains. Table 2 presents data on the number of landscaped tracts with different exposures (Kupach T., 2017, Kupach D., 2017).

It is known that the slopes of the southern exposure and with a steepness of more than 20° absorb the same amount of heat as in the south of Ukraine. Within the boundaries of the city and its outskirts, the tract with slopes more than 20° constitute ≈32%. The thermal regime of the territory is formed according to the nature of the surface and will affect the parameters of climate comfort, the prolongation of the period suitable for various types of summer recreation.

One of the meteorological phenomena that are obligatory in the assessment of climatic recreational resources, and which has a slightly restrictive effect on recreational activities, is the wind, its speed and direction. In the period of the predominance of low temperatures, the wind enhances heat transfer, which leads to overcooling. In the warm season, the wind enhances evaporation of the human skin, improves the feeling of warmth and comfort. Light wind (3-6 m/sec) has a stimulating and tonic effect on a person's self-perception. A strong wind (greater than 15 m/sec) has an irritating, tedious effect, complicates breathing processes (Danilova, 1982). Figure 3 shows the dominant wind direction for years of observation and the distribution of the number of days by months of

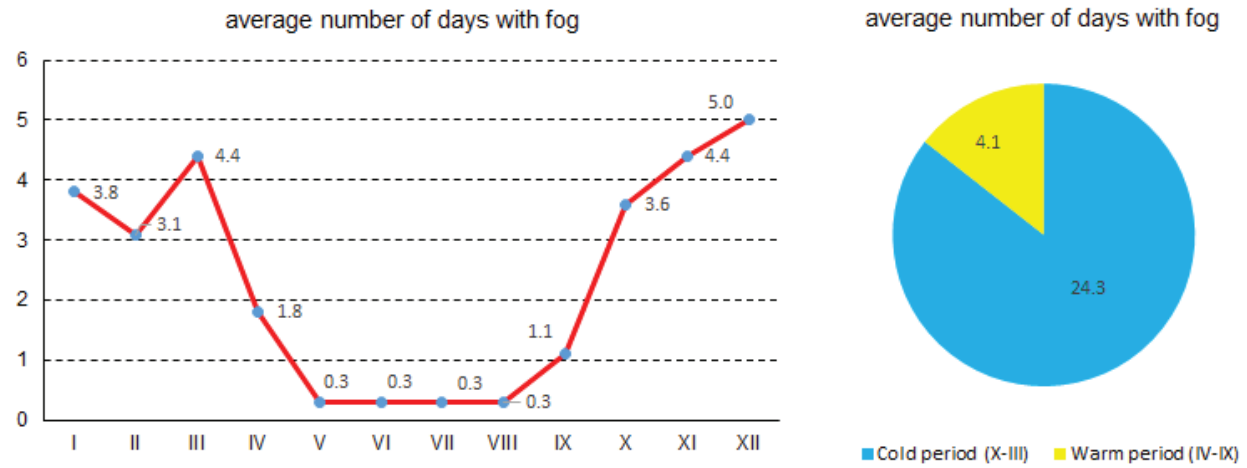

Fig. 2. Diagrams of the average number of days with fogs for different months, during warm and cold periods of the year at the meteorological station "Kaniv" for different years of long-term observations in the period from 1960 to 2010.

Table 2. Summary of the results of landscape analysis (GIS-based analysis) on the quantity and part of landscape tracts in the exposure of slopes in Kaniv for the medical-biological assessment of the territory

rhumb	degrees	number, units	fraction, %
N	315 – 45	391630	31.15635
E	45 – 135	336287	26.7535
S	135 – 225	304795	24.24814
W	225 – 315	224271	17.84201

the year with wind speeds below 10 m/sec (Danilova, 1982).

Comfortable indicators (power and speed of wind, direction) of windy weather for carrying out various types of recreational activities characterize the results of the study for Kaniv district.

Figure 4 shows the annual temperatures and the monthly average atmospheric pressure at the station level for a long-term observation period.

In recreational activities, the value of atmospheric pressure plays an important role, since the variability of the pressure indicators affects the physiological and

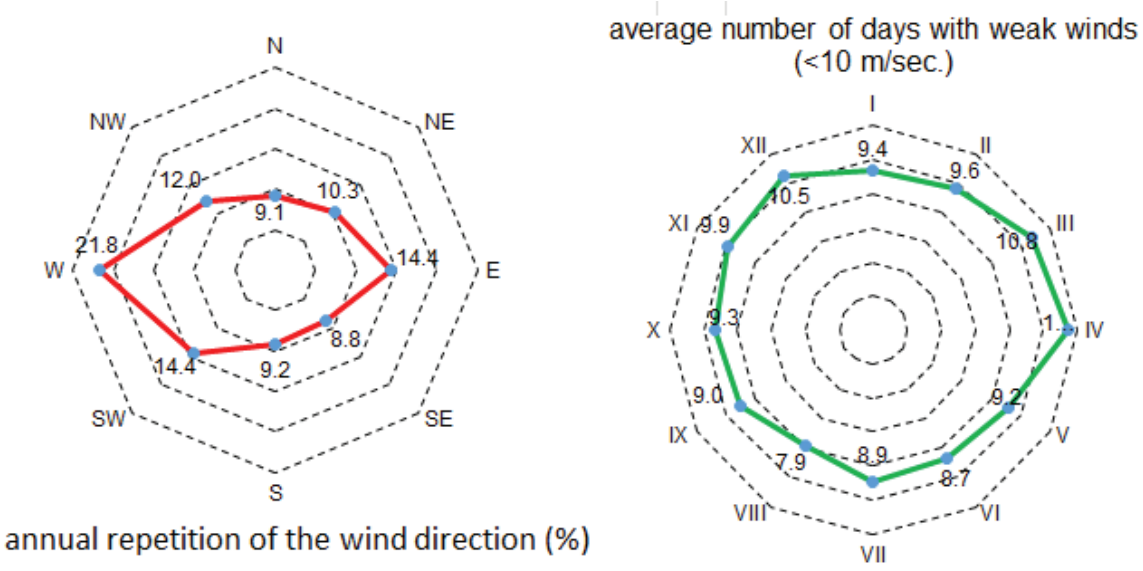

Fig. 3. Graphs of annual repetition of the wind direction and the average number of days with light winds over several years of long-term observations in the period from 1960 to 2010. (Meteorological station "Kaniv")

On average, the city experiences a temperature of >+25°C for about 60 days. The temperature determines the physiologically comfortable or uncomfortable conditions of the environment, which causes a feeling of warmth with or without signs of overheating/hypothermia .

The most reasonable indicator of climate comfort is the average daily temperature. So, numerous recreational researches establish that the zone of thermal comfort for the summer period is +15 - +20 (25)°C, for the winter 0 - -10 ° C (Danilova, 1982, Mykhailenko N., 2015, Shherban`, 2015).The average monthly temperature for most of the year is positive and reaches a maximum of +21.9°C in July, and the coolest month in the town is January with a temperature of -3°C. The average daily temperature (°C) for all months of the year in the period of observation is given in Table 3.

biological processes in the human body, in particular, the well-being through the meteotropic reactions of the organism.

Thus, in a series of studies it was established that day-to-day pressure changes of <5 hPa do not cause express reactions, at the same time, changes within 6-10 hPa become noticeable, and >10 hPa are pathological. A sharp drop or rise in atmospheric pressure during the day is considered to be a change of >8 hPa and a temperature of 4°C (Mykhailenko N., 2014, 2015, Shherban`, 2015, Mykhailenko T., 2014).

The territory of the city is characterized by a more or less equal degree of air humidity, which is also shown in Figure 4. Relative humidity of air is the highest in winter, and indicators of moisture deficit reach maximum in summer. Humidity occupies a special place, because it is an important meteorological element in recreational assessments (Danilova, 1982).

Table 3. Average daily temperature (°C) by months of the year in terms of observation period for individual years of long-term observations in the period from 1960 to 2010 (meteorological station "Kaniv")

time, hours	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
0	-6.1	-4.7	-0.2	7.2	13.2	15.8	17.3	16.8	12.2	6.5	1.7	-2.6
3	-6.4	-5.3	-1.0	5.9	11.4	14.1	15.7	15.2	10.8	5.5	1.3	-2.9
6	-6.6	-5.8	-1.7	4.9	10.4	13.4	14.8	14.0	9.8	4.8	1.0	-3.0
9	-6.7	-6.0	-1.1	7.4	14.9	18.1	19.3	18.1	12.6	5.8	1.0	-3.1
12	-5.3	-4.0	1.8	11.0	18.3	21.2	22.6	22.1	17.0	9.7	2.9	-2.0
15	-3.9	-2.4	3.5	12.7	19.8	22.4	23.8	23.7	18.6	11.5	3.9	-1.1
18	-4.8	-2.8	3.2	12.5	19.4	22.0	23.5	23.3	17.8	10.2	2.9	-1.9
21	-5.6	-4.0	1.2	9.5	16.2	18.9	20.3	19.3	14.0	7.7	2.1	-2.4
average per day	-5.7	-4.4	0.7	8.9	15.5	18.2	19.7	19.1	14.1	7.7	3.7	-2.4

Humidity influences the formation of thermal conditions of the environment, the exchange of moisture in the processes of acclimatization and adaptation, respiration processes, etc. Therefore, humidity indicators play an important role in establishing the physiological limits of climate comfort for different types of activities. The most favourable condition for people is dry and moderately dry air.

With comfortable humidity characteristics, cold and heat are much more easily tolerated by man . The physiological norm for a person is the relative humidity of air from 30 to 60%. For recreational activities (according to various studies), favourable humidity is 30-80% (Danilova, 1982).

The humidity regime in the city corresponds to an annual precipitation up to 500 mm, a maximum of 742.8 mm, a minimum of 285.5 mm. Prevalence of summer precipitation (up to 40% of the annual amount) characterizes the annual precipitation.The graph of the average monthly precipitation can be seen in Figure 4.

The precipitation patterns are often short-term, intense and torrential. Thunderstorms (May-August, beginning in March-April and ending in September-October)often accompany downpours. Figure 5 shows data on the average number of days with thunderstorms according to the weather station "Kaniv" over many years of observation.

The annual number of days with thunderstorms

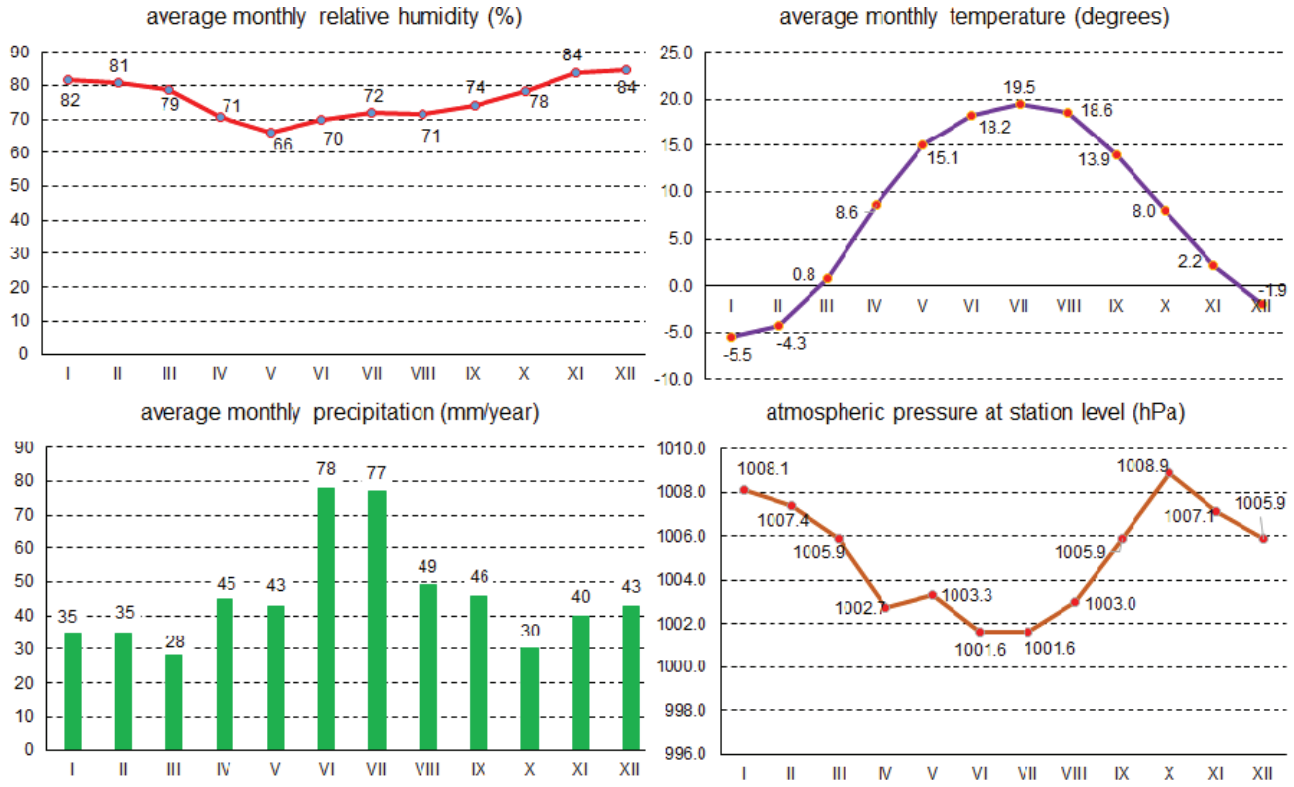

Fig. 4. Annual progress of the main meteorological elements (atmospheric pressure, precipitation, relative humidity and temperature) in the different years of long-term observations in the period from 1960 to 2010 on the meteorological station "Kaniv"

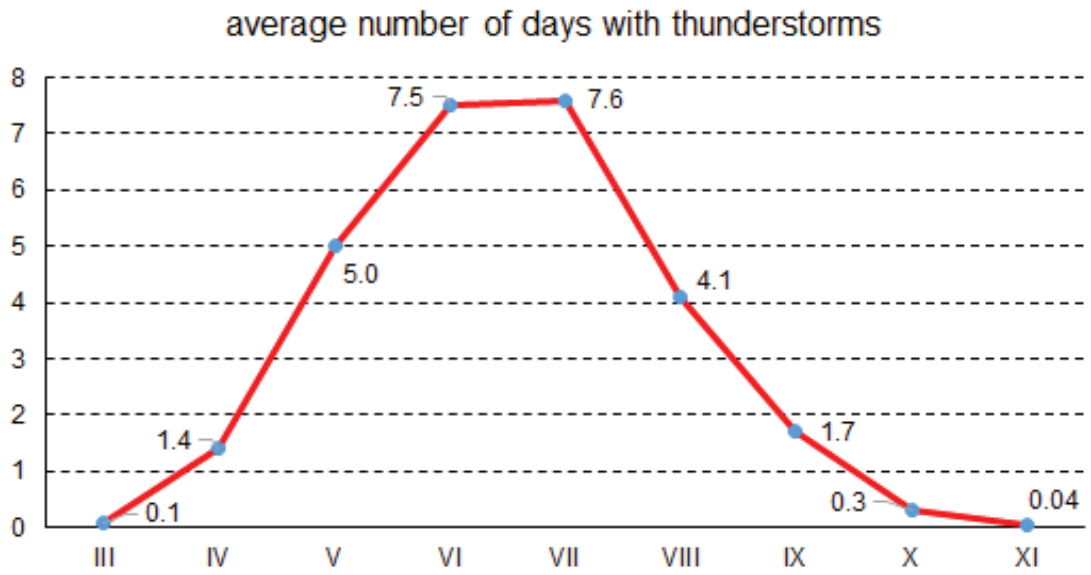

Fig. 5. Average number of days with thunderstorms according to the data of the Kaniv Meteorological Station in the years of observations from 1960 to 2010

varies in different years and is about 19–20 days (close) and 23–25 days (remote). The average annual duration of thunderstorms exceeds 60 hours. Thunderstorms belong to the limiting recreational activity factors although a number of researches indicate that this meteorological phenomenon adds advantages in terms of recreational value because of the health qualities of the air, ozonizing and purifying, making it useful for treating diseases of the respiratory system.

In winter precipitation predominates in the form of snow which forms a stable snow cover. On average, snow cover begins to form at the end of December, although snow falls in November. Snow cover remains on average until the end of March, in some years until mid-April, an average of 77 days (the maximum number of days reached 117). The greatest depth of snow cover within the city is observed on the mountainous part of the Kaniv mountains covered with forests and varies from 20 cm (winters with little snow) to 45 cm (snowy winters). A specific thermal regime of the territory forms due to the influence of surface characteristics (relief, greenery, etc.) on the redistribution of heat.Although the snow cover is sufficient for the development of winter types of active recreation, due to the interference of warm Atlantic air masses in winter, the snow cover decreases with frequent thaws, which significantly reduces the period of recreational favourability.

In characterizing the thermal regime of recreational areas, complex indicators of effective temperature (ET), equivalent-effective temperature (EET) and a number of others are often used in assessment of the favourable climatic conditions and determining their comfort for recreational activities for. So, the ET indicator takes into account the complex effect of temperature and air humidity and indicates a quantitative relationship between meteorological conditions and human thermal sensation (Danilova, 1982, Mykhailenko N., 2014, 2015, Shherban', 2015, Mykhailenko T., 2014). Table 4 shows calculations of the effective temperature and heat sensation of a person.

Significant amplitudes of heights and dismemberment of the relief forms favourable conditions for an increased flow of rainfall and melt water. Increased flow of surface water leads to good drainage of the upland areas of the city and forms flooding (with bogging processes) along the bottoms of gullies and ravines and leads to the formation of temporary streams: the Melanchine, Komashiny spur, Sukhoy streams, Slyzka ravine, Topylo gorge. Springs of Cretaceous system groundwaters cause partial flooding of gullies and flat confluence of the spurs of ravines. The debit some of them is stable throughout the year (0.2 l / s). The water of the springs has a stable temperature of 10 °C and is of high quality. The indicated distribution of the flow of surface waters determines the specificity of the natural humidity regimes and, as a result, conditions are formed that affect floristic and landscape diversity.

The main hydrological object and water recreational resource of the city is the Dnipro River. The Dnipro is a typical lowland river with a slow and calm flow. It has a convoluted channel, forms arms, a lot of rifts, islands, straits and shallows in not regulated places. The water level in the river increased, the

Table 4. Consolidated results of the evaluation of the main meteorological elements and indicators of the effective temperature in the city of Kaniv and its surroundings

months	air temperature, °C	relative humidity, %	effective temperature, °C	wind speed, m/s	cloudiness, points	thermal sensation and thermal loading	climate comfort for recreational needs • subcomfortable winter (SC) • subcomfortable summer: cool (SS c) hot (SS h) • comfortable (C) • uncomfortable (U)
I	-5.5	82	-4.384	3.3	7.3	Very cool / discomfort / moderate, possible hypothermia	SC (winter recreation)
II	-4.3	81	-3.213	3.5	7.4	Very cool / moderate, possible hypothermia	
III	0.8	79	1.573	3.4	6.8	Moderately cool / discomfort	C (winter recreation)
IV	8.6	71	8.762	3.4	6.5	Cool / discomfort / discomfort	U (summer recreation)
V	15.1	66	14.406	2.9	5.5	Moderately warm / comfort	SS c (summer recreation)
VI	18.2	70	17.216	2.6	5.5	Moderately warm / comfort	C (summer recreation)
VII	19.5	72	18.436	2.5	5.2	Warm / comfortable	
VIII	18.6	71	17.602	2.4	4.7	Moderately warm / comfort	
IX	13.9	74	13.494	2.6	5.1	Moderately warm / comfort	SS c (summer recreation)
X	8.0	78	8.176	2.9	6.0	Cool / discomfort / discomfort	U (summer recreation)
XI	2.2	84	2.699	3.4	7.9	Moderately cool / discomfort	
XII	-1.9	84	-1.138	3.4	8.1	Very cool / moderate, possible hypothermia	SC (winter recreation)

flow slowed down and the water exchange processes drastically changed after regulation through the construction of reservoirs.

The width of the Dnipro stream pool increased, the arms of the old meandering channel filled with water, forming the so-called Kryvi Ozera. The Dnipro in its middle course flows between the Dnipro Highland and the Dnipro Lowland, which determines the expressive asymmetrical features of the river valley within the city. The right bank of the Dnipro is steep, high, the left is low and gently sloping. A narrow flat right-bank lowland extends in places between the right bank and the water surface of the Dnipro. The left bank is lower, formed of sandy sediments and extends to the east in wide terraces. Within the city, the Dnipro valley is wide and reaches 15-18 km, and the channel width is up to 1500 m with a depth of 3–7 m, the speed of the current is 0.4–1.2 m /s. The middle part of the Dnipro basin is located in the forest zone of excessive and sufficient moisture. The Dnipro River is fed by rain, snow and underground springs (Hil'chevs'kij, 2014, Greben`, 2014.,Vyshnevs'kyj, 2000).

A well-defined spring flood, a low summer runoff (with periodic rain floods), regular autumn floods and a winter runoff determine the water regime of the Dnipro. Freezing begins in December (freezing ≈ 23.12) and lasts until March - April (opening of the river ≈ 22.03). The freeze-up of the reservoirs is formed and disappears later than on non-regulated sections of the channel. Freezing-over begins in December (freezing ≈ 23.12) and continues until March - April (opening ≈ 22.03).

The water regime of the river has changed significantly after the construction of the Kaniv and Kremenchug reservoirs. The reservoirs equalise the water level in the Dnipro and the ice cover is thinner below the dams (Hil'chevs'kij, 2014, Greben`, 2014,Vyshnevs'kyj, 2000).

The construction of reservoirs disrupted the ecological balance and radically changed the conditions of water exchange. Water exchange has slowed by 14-30 times compared with natural conditions. The construction of both reservoirs significantly affected the ecology of the Dnipro and coastal lands, including the growth conditions of aquatic and coastal vegetation of the Dnipro and its floodplain.

A number of species did not withstand the new living conditions, while others, on the contrary, are developing better, as a result of which the species composition of plants before and after construction and flooding has changed in all parts of the Dnipro. In the Dnipro and its reservoirs from 65 to 72 species of higher aquatic plants (macrophytes) were found. Among them, plants immersed in water (hydrophytes) of about 33 species and plants with floating leaves (hydatophytes) of about 19 species predominate. Among the plants adapted to the conditions of growth in the shoreline strips (air-water conditions) are about 20 species (Koreljakova, 1977).

In recent years, there is an intensive overgrowth of the shoreline areas of Kaniv beaches and an active bloom of blue-green water plants occurs here. A number of environmental problems such as climate change, reducing the period with temperatures below zero degrees and reducing the period of freezing of the reservoir, reducing fish population of the Dnipro, and the increase in pollution with phosphates and nitrates due to intensive chemicalization of agricultural production, affect the recreation and tourism in the city.

However, the level of pollution of hydrological objects of the city does not exceed the allowable values. Carrying out cleaning measures and technical cutting, etc. solves problems of overgrowing by shrubs of the beaches.

The city of Kaniv with its surroundings due to the presence and harmony of climatic and hydrological conditions is quite promising for organizing medical and recreational, beach recreation and water tourism of various types: rest, recreational aerotherapeutic, hydrotherapeutic, beach-swimming recreational activities and organization of chain institutions of the resort and medical direction.

Technological assessment of the suitability of a water object for recreational activities, in particular, bathing and beach recreation, includes the analysis and evaluation of the following indicators and parameters (see Table 5) of the water object and adjacent areas (the area from Dnipro Heroes Street along T. Shevchenko Street to Tarasova Gora).

The nature of the relief and sediments, vegetation also determines the significant favourability of a number of technological parameters for assessing the hydrological object for beach and bathing recreation (Kulinich, 2016, Danil'chuk, 2003, Alejnikova, 2003, Bovsunovskaja, 2003, Golubnichaja, 2003). Apart from the said parameters of the water object which are used for swimming and beach recreation, technological assessment also applies to the suitability of the water area for active types of tourism and recreation: boating, catamaraning, canoeing, kayaking, yachting and using other watercraft.

Technological indicators (width, length, depth of water area, current, direction and speed of wind, number of days with calm, etc.) of the Dnipro river in the area of the city satisfy the conditions for the implementation and organization of such types of recreational activities (Kulinich, 2016). Table 6 summarizes the technological parameters of the Dnipro River within the city (area from the Dnipro Heroes Street along T. Shevchenko Street to Tarasova Gora).

The natural recreational conditions of the territories is formed by biotic resources because vegetation cover directly affects the flow of climate processes ,the formation of landscape diversity, hydrological processes and others .In relation to other recreational resources ,natural resources create highly attractive conditions in any territories.Biotic resources, combining all the diversity of wildlife, have medicinal properties, scientific and cognitive, biomedical and aesthetic value and are involved in the processes of human recovery and rest (Fomenko, 2007.,Tsarik, 2001,Chernjuk,2001). The available biotic resources are favourable for treatment and rehabilitation, as well as satisfaction of the spiritual needs of humans and the organization of separate types of tourism(for example, hunting tours,tourist fishing,etc.)

Forests of recreational value and greenery of the city represent the biotic recreational resources of Kaniv and lands of the Kanivsky Nnature Reserve and fauna of hunting and fish farms too. Wildlife resources are favourable for the rehabilitation, treatment and prevention of human diseases and technologically necessary to meet the recreational needs and the organization of certain types of tourism (hunting tours, fishing tours, scientific tours).The attraction of wildlife resources for recreational activities varies in its manifestations and nature: picking mushrooms and berries, fishing, walking and health paths, excursions and scientific tours, phytotherapeutic treatment and rehabilitation, landscape routes and excursions,visiting

Table 5. The evaluation criteria and the degree of suitability of the Dnipro River within the city of Kaniv for recreational activities during the warm period (Kulinich, 2016)

evaluation criterion	criterion value	degree of recreational favourability
shore	dry, with steep slopes requires simple structures for descent to the water	relatively favourable
water approaches	open	favourable
beach	sandy	favourable
the extension of the shallow, m	10-50	favourable
bottom	sandy	favourable
number of days with water +19-24 ° C	>70	favourable
current flow, m / s	0,3-1	relatively favourable
maximum depth, m	>1,8	favourable
degree of overgrowing,%	<5	favourable
water turbidity	slightly cloudy	relatively favourable

places of unique species,birdwatching and nature photography,etc.

Forest and urban greenery (roadside zones, parks, squares, and areas near houses and gardens) represents recreational plantings of Kaniv and its near surroundings.

The right bank of the city and its suburbs covered by recovered broadleaf forests with hornbeam, European oak, European ash, wych elm, small-leaved lime, field maple, Norway maple, Tatar maple, black locust,white poplar, quaking aspen, *Populus pyramidalis*, silver birch, European spindle, regent spindle *Euonymus verrucosus*, etc. The ornament of forest lands is the open areas of steppe meadows. The steppe meadows are a characteristic part of the upland plakor part of Kaniv dislocations. Xerophytes, psammophytes, a wide variety of grasses (fescue, windgrass, orchard grass , bushgrass, Junegrass, immortelle, hare's foot clove, *Potentillia argentea*, strawberry, *Euphorbia cyparissias*, oregano, yarrow, etc.) represents meadow steppe flora , which contain a large proportion of rare species and valuable medicinal plants. In recent years, processes of secondary succession have taken place within the open spaces of the mountainous part. This has been accompanied by the spread of shrubby and tree species such as Scots pine, wild pear, blackthorn , hawthorn, oleaster and dog-rose. The shoreline water protection zone of the Dnipro River is planted with white acacia, weeping willow and white willow. On the left bank of the city and its vicinity grow pine and mixed coniferous forest of pine-forest terrace of the Dnipro River, which have the greatest recreational value. Common pine with an addition of European oak, rowan, white acacia, blackberry, red elderberry, etc. form the terrace's forests. Meadow plant groups are represented on the floodplain terrace of the Dnipro River. Such floristic diversity affects the physiognomic, colouristic aspects of landscapes, enhances the landscape and aesthetics of the territory, increasing the attractiveness of landscapes of the city and its surroundings.

Microclimatic features (temperature, moisture and radiation balance), ionization and phytoncide effect of the air explains the recreational influence and

Table 6. Criteria for technological assessment and the level of suitability of the Dnipro River in the city of Kaniv for recreational activities during the warm period (Kulinich, 2016)

recreational activity	water area, hectare	length of water object, m	width of water area, m	depth of water object, m	recreational level of availability
canoeing, kayaking and rowing boats	>10	>2200	>90	>3	high
motor boat rides	>50	2000-15000	>200	>3	high
sailing	>100	>2500	500-2000	>2	high

value of the forest vegetation. The recreational attractiveness of the forest plantations is enhanced by the variety in species and age composition of the plant species, that is, the frequency of changes in landscape pictures and their aesthetics. In terms of phytoncide effect and air ionization, the most valuable trees for recreation and health improvement in the city and its surroundings are pine, pine-oak, hornbeam and oak-hornbeam forest plantations. Introduction of European ash, small-leaved lime, white poplar and *Populus pyramidalis* only increase the health value of the forests that cover the mountainous areas and territories adjacent to the Kaniv city (Gensiruk, 1987, Nizhnik, 1987, Voznjak, 1987, Fomenko, 2007).

Animal species characteristic of the forest-steppe natural zone are also components of the faunal recreational resources of the city and its environs. The number and recovery of wild animal species justifies the maintenance of the conservation status of the territories and the activities of the scientific department of the Kanivsky Nature Reserve and specialized farms. The following species of wild animals inhabit the territory of the Kaniv Nature Reserve (the forest lands of which fall within the administrative boundaries of the city): red deer, roe deer, wild boar, hare, red squirrel, stoat, marten, weasel, beaver, otter, white-tailed eagle, woodpeckers, the grey heron, great white egret, cormorants, ducks and other mammals and birds, reptiles and amphibians. There is very diverse world of insects, among which the most famous are the stag beetle, rhinoceros beetle, peacock butterfly and others. In the Dnipro River, there are almost 70 species of fish, in the area of the Kaniv city up to 40. The most common is carp. Due to the increases of pollution of the Dnipro River the quality of the environs is worsening and fish resources of the Dnipro are declining. The number of European chub, asp, and tench have decreased. Lake species, such as bream (about 40% of the total catch), pike, sabrefish, zander, catfish, carp, perch, grass carp and bighead carp take their place. Also in the Dnieper, there are two types of crayfish: long-toed and thick-toed (Degodjuk E., 2006, Degodjuk S., 2006).

There is a special place for objects and territories among natural recreational resources of the nature reserve fund, which include the Kaniv Nature Reserve, and lands of water protection and soil-protective significance. Nature protected areas play an important recreational role. They perform a popularization and educational function and play an important role in the development of organized tourism and scientific and educational excursions.

The concentration of cultural heritage sites (in addition to the natural resources) confers a high degree of recreational and tourist attractiveness upon the city and surrounding areas.

Thus, among the archaeological monuments there are places of temporary settlements of semi-nomadic tribes on the Knyaga Mountain, places of settlements of agricultural tribes of the Middle Dnieper culture on Moskovka Mountain and at the foot of the Big and Small Horodyshe within the Kaniv Nature Reserve (Liubitseva, 2017, Romanchuk, 2017, Kochetkova, 2017, Vynnychenko, 2017, Mykhailenko, 2017). The settlements of the Zarubinetska culture have been excavated and explored on the territory of modern Kaniv (Moskovka and Pilipenkova Mountains). Nearly twenty settlements of the VII-IX centuries have been found near the town of Kaniv , nine of which are in the territory of the city and the Kaniv Nature Reserve (Bondar, 1959). The settlements are located on the slopes of the right bank of the Dnipro, sometimes at the mouths of small rivers or ravines. Within the city, there are settlements between the Seltso area and Moskovka Mountain, in the Izkovshina ravine, on the Iskova (Lysaya) mountain, on the Sorokopudova, Pilipenkova, Tarasova (Chernecha) mountains. There are four such settlements within the Kanivsky Nature Reserve: at the foot of the Big and Small Scythian Horodyshe and Maryina Mountain. One of the spiritual centers of Ukraine is located in the Kaniv city, the National Shevchenko Reserve, where in May 1861, the outstanding Ukrainian master and poet Taras Shevchenko was buried in May 1861 on Chernecha Mountain.

Among the architectural and historical monuments of the city, it is worth mentioning the sites from the Cossack era, the Second World War and relating to individual historical and cultural figures and personalities.

The main architectural attraction of Kaniv is the Uspenskyj (the first name of St. George) Cathedral. Prince Vsevolod built the cathedral during the time of the Kievan Rus in 1144. The Uspenskyj Cathedral of Kaniv is one of the few monuments of the Old Russian architectural school that have survived to this day along with the Church of St. Cyril in Kiev, the Transfiguration Monastery, Borisoglibsky and Uspenskyj Cathedrals, Ilyinsky, and Pyatnitsky Churches in Chernihiv. The facades and portals of the temple were decorated with frescoes. In 1587 Hetman, Ivan Pidkova, was buried here. Destroyed by the Turks in the XVII century, the temple was restored in 1805 with changes in architectural forms in the style of classicism and the practical loss of all wall paintings. During the restoration in the period of the late 1960s frescoes– old Ukrainian elements of

painting, were discovered. In 1993 all, the restoration work was completed and the cathedral was transferred to the UOC religious community of the city.

The House of the Basilian School (a two-storied house of the former Basilian school founded by the Uniates in 1781 and financed by the then owner of the city – Count S. Ponyatovsky) is another architectural monument of Kaniv. Now it is the Museum of National Decorative Art. In the center of the city, several more buildings of the XIX century are preserved.

The memorial complex, located on the Dniprova (Zamkova) Hill in the Park of Slava, in memory of those killed in the battles for their homeland , is dedicated to the Soviet soldiers who were killed during the Second World War, were born in the city or died for it in the fight against the German occupation forces. The Monument to the Heroes of the Armoured Train # 56 , which is a full-size armoured train , was installed at the entrance to Kaniv in 1980 on the 35th anniversary of the Victory. It has been part of the exhibition of the Museum of Military Equipment in the Open Air since 2012. An armoured boat is installed on the Dnieper embankment – Monument to the Sailors of the Dnieper Military Flotilla. Built on Kyivska Street in the south-western outskirts of the city, a monument perpetuates the memory of 1250 residents of Kaniv (Sorokopud, 2012) shot by the German military in 1943 in Berestovetsky Ravine. Near the Museum of National Decorative Art is a bust of Oleg Koshevyj ,who headed the youth underground in the Donbas during the Second World War and before that had lived for a while in Kaniv (the house where he lived is preserved). There is a grave monument of the Soviet writer Arkady Gaidar, who, being a correspondent on the front line, was killed near the village Liplava in 1941. In the center of the city there are monuments to Kaniv's soldiers who died in the Afghan War and to the victims of the Chernobyl accident (Bondar, 1959)

Near the Monastyrok tract is a monument to three Cossack hetmans whose life and activities were closely intertwined with the lands of Kanivshchina: Ivan Pidkova, Samiylo Kyshka and Yacob Shah. A monument to St. Macarius, the venerable martyr, Archimandrite of the Uspenskyj Cathedral , who was tortured and executed in 1678 during the attack of Turkish troops on Kaniv , is erected at the Uspenskyj Cathedral. The relics of the canonized saint are now preserved in the Volodymyr Cathedral of Kyiv (Fialko, 2003). There is a tomb monument to the Russian actor Olexander Lensky who died in 1908 and was buried in the village Selyshe on the Trakhtemiriv peninsula. However, when the grave was threatened by the rise in the level of the waters of the Dnipro River in 1955, it was transferred to Kaniv. The monument to Vyacheslav Chornovil in Kanev was the first installed to him in the country. New commemorative signs mark the events of recent years. In early 2015 a memorial sign was opened in honor to the Heroes of the Heavenly Hundred. In the center of the city, near the chapel, a memorial sign "To the Defenders of Ukraine" was installed, dedicated to the memory of soldiers fighting in eastern Ukraine against foreign aggression at the end of 2015.

The names of prominent figures of the Ukrainian nation are associated with Kanev - M. Bilyashivsky, V. Vynnychenko, M. Maksymovych, T. Shevchenko, M. Gogol, M. Vovchok, N. Leskova, A. Malyshko, V. Sosyura, P. Tychyna and others. M.F. Bilyashivsky is rightfully considered the founder of the Kanivskyj Nature Reserve.

The combination of material and physical objects, whose activities are aimed at meeting the needs of tourists, represents Kaniv's socio-economic resources and tourist infrastructure. An integral part of tourist services is accommodation facilities, which have a direct impact on the formation of the tourist potential of the city. The total number of rooms, their condition and capacity affects the flow of tourism and prospects for the development of tourism on the local level. There are six accommodation establishments in Kaniv: the Knyazha Gora Hotel, Karat Hotel and Tourist Complex, the Hotel Complex Zamok Roda, the Old Kaniv Hotel, house-hotel of individual type and hostel in the Kanivsky Nature Reserve. The total number of rooms is 59 (Liubitseva, 2017, Romanchuk, 2017, Kochetkova, 2017, Vynnychenko, 2017, Mykhailenko, 2017), the cost of accommodation starts from 200 UAH per day. These accommodation facilities are able to satisfy the needs of various categories of tourists – from unpretentious to demanding in the level of comfort. The location of the accommodation has a good geographical position relative to the city center, as well as transport stops.

There are 32 restaurants with 1391 places in Kaniv. They are located in the center or along the main streets of the city: O. Koshevogo, T. Shevchenka and Heroes of Heavenly Hundred.In the last two years, some establishments have closed for short periods in summer for technical reasons. All establishments are focused mainly on Ukrainian and European cuisines, less often - Asian (Biznes-kataloh pidpryiemstv Ukrainy, 2017).

For leisure activities, tourists are offered entertainment facilities, which are located in the city center and along the Dnipro. The activists of the project "VeloKaniv", staff of the museum institutions

of Kaniv region developed five cycling and several walking routes. Thanks to the first Contest of the Public Budget projects held in 2016, several tourist facilities were reconstructed and created in the city: a series of murals in the central part of the city, a square near the Magnit plant and steps to a historical and cultural monument, the Korolev Well, were created. Information and direction signs were set up on the T. Shevchenko Street (Liubitseva, 2017, Romanchuk, 2017, Kochetkova, 2017, Vynnychenko, 2017, Mykhailenko, 2017).

One of the forms of leisure and cultural enrichment is visiting museums. In the city there are several museums: Taras Shevchenko Museum, Kaniv Historical Museum, Museum of National Decorative Art, Kaniv Museum of Nature, Museum of Literary Kaniv Region and Club-Museum of War Veterans. An international film festival has been held in August since 2016 in the local House of Culture. It is planned to complete the construction of another House of Culture with 700 places under the direction of the Shevchenko Cultural Center. The date of commissioning is unknown. There is rental of bicycles and electric cars for children on the embankment of the Dnipro River.

One of the important components of the tourist infrastructure is transport. There are five bus and taxi routes in the city. Highways of regional and local significance pass through the Kaniv area. The requirements for intercity traffic are satisfied by the bus station "Avto-Rika", which is equipped by necessary services for inter-city transportation of passengers. Three are three main directions: Kyiv, Cherkasy and suburban. One route goes to Dnipro city. Buses depart at intervals of from 5 to 50 minutes. (Biznes-kataloh pidpryiemstv Ukrainy, 2017). Roads in the city center are not always safe and well maintained: some pedestrian zones and clear roads signs for drivers are absent, so there is a possibility of traffic accidents.Today there is no railway connection to the city following the explosion of the railway bridge in 1943. The nearest railway station is in Myronivka city. One of the priorities in the development of transport infrastructure is river transport, which can serve both domestic and foreign guests. The presence of the Dnipro River, the third in length and basin area in Europe, determines the modern development of the industry not only in freight traffic, but also in tourist traffic. The river transport industry of the city is represented by enterprises and infrastructure: "Auto-Rikar" Subsidiary and "Tarasova Gora" pier (Biznes-kataloh pidpryiemstv Ukrainy, 2017). By the mid 1990s the Dnieper was cruised as regular intercity transport by the motor rocket ships "Polissya"," Rocket" and "Meteor" from Kiev to Kaniv. Cruise routes of international importance passed through Kaniv. Only in 2016 after a long break, was the Kiev-Kaniv passenger voyage relaunched. It became an excursion route, which includes travel in both directions, visits to museums, the Tarasov Mountain and excursion services.

Conclusions. After analyzing and determining the level of favourability of the recreational resources of the city and its surroundings for the organization and implementation different recreational activities, we can make the following conclusions. According to the high degree of favourability of separate groups of recreational resources, the Kaniv city can specialize in the following types of recreational activities:

- Organization of therapeutic-wellness recreation, namely, climatotherapy (helio-, aero-, hydrotherapy), landscape therapy (viewing of the landscapes, walks by observation routes, audio and phytotherapy)

- Wellness and sports health recreation, namely beach- swimming recreation, healthpath walking and hiking, bicycle recreation and tourism, water recreation and tourism (by rowing, sailing, pedal boats, water skiing, hydro cycles, etc..), hiking and so on;

- Cognitive recreation and tourism, namely cultural, event, scientific tourism, excursions of natural, historical and cultural direction, hunting and fishing tourism, and so on;

- Eco-tourism, namely visiting the formations of geotourism objects network, birdwatching, botanical tours and nature photography. Development and implementation of excursions by routes to the "Trakhtemyriv" historical and cultural reserve, scientific and educational excursions by the ecotrail and an eco-route within the Kanivsky Nature Reserve, the regional landscape park "Trakhtemyriv", etc .;

- Business (congress) tourism using the socio-economic infrastructure resources in addition to natural, historical and cultural resources. Formation of services package and services for holding congresses, conferences, symposia, forums, festivals, etc.

However, the availability and condition of the Kaniv's socio-economic infrastructure and its environs indicates an insufficiently high level of security and comfort for the development of recreation and tourism in the city. Therefore, despite the significant potential for therapeutic recreation, the city is not provided with resort health and treatment facilities, as well as recreation centers, and insignificant mass recreation facilities are accessible both to the city's population and to external tourists. The organization

and development of the resort business in the city requires large investments and reanimation measures. The arrangement for recreational activities of the shore zones and the banks of the reservoir also requires significant funding and redesign according to the current requirements of environmental legislation, territorial planning of the city, and so on. Parks or squares and other green areas of the city also have an aesthetic function and affect the overall perception of the city and, therefore, require additional equipment and care. However, the economic and humanistic effect of the introduction of this type of activity in the region is justified by the resource potential, the possibilities of both the environment and the interest of the population.

The transport and information infrastructure of the city and its surrounding areas also requires objective investments in growth and development. Due to the insufficient development of the city's road transport and information infrastructure, most of the monuments and tourist sites remain poorly integrated into the tourist routes.

Recently, the city has seen an increase in the development of accommodation facilities, catering and cultural leisure activities. There is a general trend towards arranging territories and hospitality facilities using authentic elements (local cuisine, stylized interiors, using unique elements in architecture and decoration, design, etc.), which increases the attractiveness of the city for tourists. In recent years, the city has seen a general trend towards the development of various types of congress (business) tourism (holding conferences, seminars, congresses, creative competitions, etc.), event tourism (holding festivals, exhibitions, fairs, etc.).

The recreational potential of the territory of the city of Kaniv and its environs is significant and can be easily transformed into an economically promising and high-quality consumer product. The result of a balanced use of natural and cultural heritage and available socio-economic resources would be an increase in economic indicators (such as employment, business activity, growth of financial indicators of business activity), improvement of demographic indicators (for example, decrease in labour migration), increased human development and quality of life for residents.

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Economic and geographical aspects of research into the economic potential of the Carpathian region

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Abstract. The article clarifies that during the administrative and territorial reform in Ukraine an important role is played by the capacity of the territory and the efficiency of the economic -managerial operations, in the assessment of which the most significant indicator is the availability of economic potential of the territory. Regarding the natural and geographical aspects of the research of the territorial structure of the economic complex of the Carpathian region, this region has a substantial natural capacity for the development of economic potential. Therefore, this region has all the preconditions to become one of the most developed regions of Ukraine . There are different classifications of the resources which make up and form the natural potential of the region. One of them is the allocation of resources according to the production spheres and industries where they can be applied, such as agricultural; non-productive; industrial. When it comes to the economic aspects of the research on the territorial structure of the economic complex of the Carpathian region, their dynamics are determined by the demographic situation of the region. Their dynamics are characterized by decrease in the rural population, cutback of the growth rate of the rural population, its ageing (individuals over 70 years old take up the largest share in the general age structure of the population), and emigration of young people, which is observed alongside some positive tendencies in birth rate increase. Accordingly, the processes of labour force ageing negatively affect the informational enhancement of all spheres of economy functioning throughout the region. This is connected with the failure of the region to embrace the state-of-the-art technologies. Such a demographic situation has influenced the structure of the labour market, the formation of which is accompanied by the release of a significant amount of labour resources and the deterioration of the situation in occupation and employment. At the same time, the freeing up of border crossing has contributed to the mass emigration of villagers to neighbouring countries seeking for employment. This has happened as a consequence of the economic processes that have taken place in the region, which are: high unemployment, prevalence of part-time jobs, and low wages. When we take into account the available and favourable natural, economic, scientific and technical factors in the development of the economic complex in the region, its historical and geographical inheritance, it is clear that strategic goals should include reasonable use of natural, material and technical, labour and intellectual capacities, and creation of an effective economic system. Such a system has to be able to provide material needs of various industries of the territorial economy and increase the level of environmental safety in the region. Herewith, based on the received data on the socio-economic and ecological status, we have identified are some main priorities for developing the Carpathian region. These priorities are as follows: development of tourist and recreational, agricultural and industrial, and forestry complexes; development of the non-productive sphere (especially in the area of mountainous territories); increase of the economic development of the Carpathian region; protecting the environment and raising the responsibility for the irrational use of natural resources and large amounts of pollutant emissions into the environment; taking measures to restore the historical and cultural traditions of the Carpathian region.

Key words: territorial structure, economy, economic complex, economic potential, the Carpathian region.

Економіко-географічні аспекти дослідження господарського потенціалу Карпатського регіону

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Анотація. У статті з'ясовано, що в Україні під час проведення адміністративно-територіальної реформи важливу роль відіграє дієздатність території та ефективність функціонування господарства, при оцінюванні чого найважливішим по-

казником є наявність господарського потенціалу території. Що стосується природно-географічних аспектів дослідження територіальної структури господарського комплексу Карпатського регіону, то він володіє значним природним потенціалом для розвитку господарського потенціалу, а отже має всі передумови, щоб увійти до числа найбільш розвинених регіонів України у цьому відношенні. Існують різні класифікації ресурсів, що входять і утворюють природний потенціал регіону. Одним з них є розподіл ресурсів відповідно до сфер і галузей виробництва, де вони можуть бути застосовані: сільськогосподарські; невиробничі; промислові. Що стосується економічних аспектів дослідження територіальної структури господарського комплексу Карпатського регіону, то їх динаміка зумовлена демографічною ситуацією регіону, яка характеризується зменшенням сільського населення, скорочення темпів приросту сільського населення, його старінням (особи, віком понад 70 років становлять найбільшу частку у загальній структурі населення), еміграцією молоді, деякими позитивними моментами щодо збільшення народжуваності. Відповідно, процеси старіння трудових ресурсів негативно впливають на інформатизацію усіх сфер функціонування економіки регіону у зв'язку з неспроможністю останніх до освоєння новітніх технологій. Така демографічна ситуація вплинула на структуру ринку праці, формування якого супроводжується вивільненням значної кількості трудових ресурсів та погіршенням ситуації у сфері зайнятості та працевлаштування. У той же час, вільний перетин кордону сприяв масовій еміграції селян до сусідніх держав з метою працевлаштування. Це стало наслідком економічних процесів, які відбувалися у регіоні: високий рівень безробіття, неповна зайнятість, низький рівень оплати праці. Зважаючи на наявні в регіоні сприятливі природні, економічні, наукові та технічні фактори розвитку господарського комплексу, його історична та географічна ретроспектива, стратегічні цілі включають оптимальне використання природного, матеріально-технічного, трудового та інтелектуального потенціалів, створення ефективної економічної системи, яка здатна забезпечити матеріальні потреби різних галузей територіальної економіки та підвищення рівня екологічної безпеки регіону. При цьому, спираючись на отримані дані щодо соціально-економічного та екологічного стану, серед основних пріоритетів розвитку Карпатського регіону є розробка туристично-рекреаційного, агропромислового, лісопромислового комплексів, розвиток невиробничої сфери (особливо на території гірських територій), підвищення економічного розвитку Карпатського регіону, охорона навколишнього середовища та підвищення відповідальності за нераціональне використання природних ресурсів та великі обсяги викидів забруднюючих речових у навколишнє середовище, здійснення заходів щодо відновлення історико-культурних традицій Карпатського краю.

Ключові слова: територіальна структура, господарство, господарський комплекс, господарський потенціал, Карпатський регіон.

Introduction. In the modern world, the capacity of certain territories is one of the most important pledges of the successful prosperity of a country. So in Ukraine during the process of administrative and territorial reform, a crucial important role is played by the capacity of the territory and the efficiency of the economy, in the assessment of which the most important indicator is the availability of the economic potential of the territory.

For the recent period of time, socio-economic and political transformations in Ukraine and the country's desire for full integration into the world's economic community have facilitated some positive changes. First of all, they contribute to the formation of new ways and mechanisms of national development, and influence on the development of industrial relations in various spheres of economic activity, and on the assessment of the role of resource factors in production and provision of social development and well-being. Regarding this, a special approach is required for such a sphere of vital importance to society as use of natural resources.

The modern global concept of socio-economic development, on which the future of mankind is oriented, along with social and economic factors of social development, distinguishes as primary, the natural component and relates the sustainable development of civilization to the use of a number of necessary measures and restrictions in order to avoid irreversible destructive changes in the natural environment. This requires careful use of natural resources. Considering this, the main purpose of the article is to analyze the economic and geographic aspects of the study of the economic potential of the Carpathian region.

Material and methods. In the course of our research, economic and geographic aspects of the study of economic potential of the Carpathian region have been investigated. The information base of the study was provided by monographs, scientific and analytical publications by domestic and foreign authors; official data of the State Statistics Service of Ukraine and regional statistical services of Lviv, Ivano-Frankivsk, Chernivtsi and Transcarpathian regions, etc. The study used both general scientific (systematic approach, structural analysis and synthesis, literary, mathematical and statistical, and historical methods), as well as special methods (comparative and geographical, classification and typology, regionalism, zoning, and expeditionary method).

Results and their analysis. The analysis of the productive forces of the Carpathian region and their development through the prism of the current economic and geographical situation allows one to form a real assessment of the effectiveness and prospects of development of the entire territorial structure of the economic complex. Despite the economic achievements of previous years, it should be noted that irrational and sometimes foolish economic policy and false management actions have

led to the formation of a non-vital and deformed economic system in the region that has lost its social attractiveness and economic efficiency, and poses an environmental threat to the region. This has led to the accumulation of a range of social, economic and environmental issues that require immediate solution. The analysis of the socio-economic situation in the region according to the criteria of present day and the search for optimal ways of sustainable development requires attention to be paid to negative phenomena that have become relevant in the recent years. As O. Olshanska, M. Fashchevskyi, and I. Bilokon point out, the territorial structure of the economy can be considered as a means of reflecting the interconnection of various elements of the structure of industry, in which an inseparable system of natural resources, society, production spheres, service, and infrastructure is treated as a complex of branches of social life (Ol'chans'ka, Fachevs'kyj, Bilokon ', 2009) (see Figure 1). This interpretation overlaps with the notion of "branch structure", which is determined by the ratio by type of economic activity.

We agree with O. Dobrovolska that the territorial structure of the economy of the region includes territorial branch subsystems, such as industrial, agricultural, transport, etc. According to O. Dobrovolska, the territorial structure of the economy of the region involves the dimensional organization of various types of production on its territory, with the establishment of close interconnections between the economic centre (s) of the region and the areas (Dobrovol'skaia, 2007).

Territorial structure arises, based on the territorial division, integration processes of labour and specialized mechanisms of the economy. This concept combines different types of productive means and the distribution of human resources, considering social and territorial development and the state of the ecology. These are the means of the territorial structure of the economy and the outspread of society, along with means of natural resource potential, economic and geographical position and geopolitical location, socio-economic regional indicator and product competitiveness, which are indicators for determining the geo-economic potential of the state (Maniv, Luts'kyj, Maniv, 2007).

Thus, the territorial structure should be understood as a set of territorial relations between individual production facilities. It should also be noted that the level of development of territorial structures has a substantial impact on the functioning of the economic complex of the country as a whole.

Comprehensive economic development of the region is based on the consolidation of market industries of national importance, industries that provide for the needs of the population and the development of leading industries and sectoral infrastructure. A complex approach to the development of a regional economy involves the formation of stable economic and inter-branch links, which will also facilitate the development of the sphere of services of the territorial complex.

All regions, economic regions, have specific natural and resourceful potential and their indigenous features of the economy and social factors, which are prominent aspects in establishing their economic profile. Regions should be understood in terms of economic unity, territorial economic organization, the main milestones of which are market specialization (Hajdenko, 2018) is.

With regard to the natural and geographical aspects of the study of the territorial structure of the economic complex of the Carpathian region, this region has a significant natural potential, and therefore has all the prerequisites to become one of the most developed regions of Ukraine in this respect. There are different

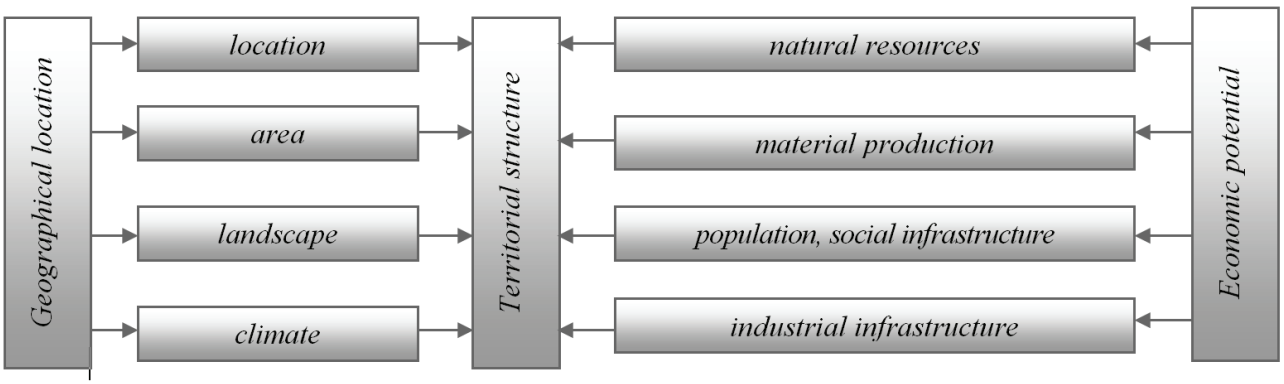

Fig. 1. Scheme of the influence of geographical position and economic potential on the territorial structure of the economy *

**- the author's own development*

classifications of resources that are included in and form the natural potential of the region. One of them is the division of resources according to the spheres and industries where they can be applied: agricultural, which includes all the resources needed and involved in agriculture, such as soil , land , natural and climatic resources ; non-productive, which are resources not involved in economic activity, but necessary for the normal functioning of society; industrial, which are a set of resources involved in economic activity and industrial production.

In the context of the analysis of the economic and geographic aspects of the study of the territorial structure of the economic complex of the Carpathian region, it is worth noting that it includes four administrative regions: Lviv, Transcarpathia, Ivano-Frankivsk and Chernivtsi (see Figure 2). Let's consider the features of the natural and geographical location of each of the regions more rigorously (Dovhan ', 2005):

1. Lviv region. It is located in the western part of the country. The territory is 21.8 thousand square kilometres. The area of Verkhniobusk Lowland, located in the north, is marshy in patches; the Podillyan Upland and Roztochchya are located in the centre, in the south there are the Prydnistrovskyi depression, foothills and the Ukrainian Carpathians, which include the Beskyds and the Vododilni ranges. There are significant deposits of natural resources in the region, including oil, natural gas (in the Pre-Carpathian oil and gas region), coal reserves (Lviv and Volyn coal basin), potassium and rock salt (Stebnyk potassium salts deposit), sulphur, ozocerite, and building materials. There are several wells with mineral elements, which are the basis for the establishment and operation of spa health resorts (in particular Morshyn and Truskavets). The area is marked by a moderately continental climate, warm summer, and there are frequent thaws in winter. The mountainous climate has a more severe character. In January, on the Podillyan Uplands, the thermometer reaches -4.7 ° C, in the Pre-Carpathian territories -6.1 ° C, the Carpathians have a temperature of -6.6 ° C ; in July the temperatures for these areas are +18.7 ° C,

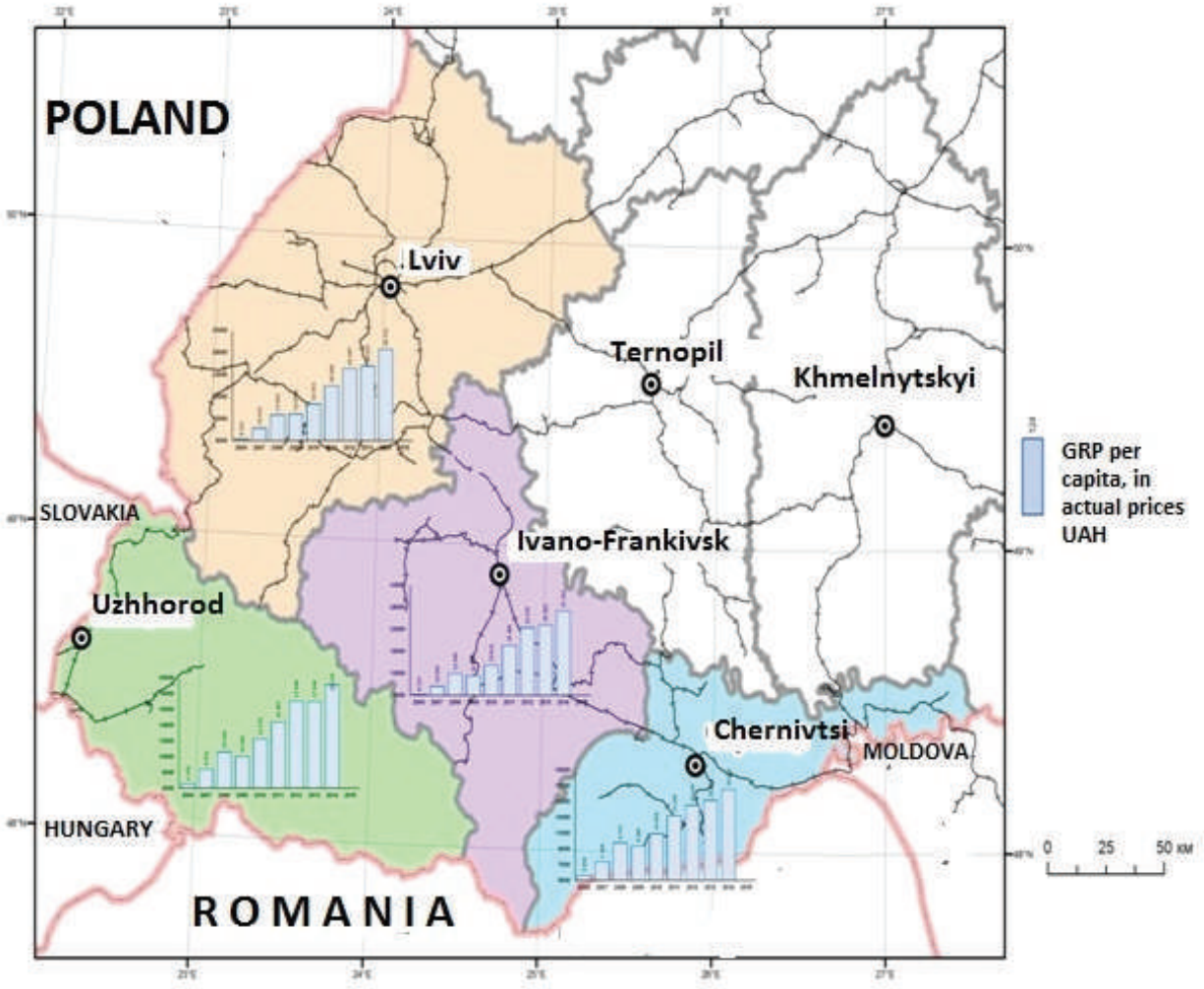

Fig. 2. Territorial structure of the Carpathian region*

*- by materials (Dovhan' H. D., 2005)

+18 ° C, +16 ° C , respectively. The precipitation on the territory of the Podillyan Uplands is 641-742, in Pre-Carpathians 685-773, in the mountainous area it is up to 1000 mm per year. Most of all, this indicator rises during summer .

2. Transcarpathian region. It is located in the western part of the state. The territory is 12.8 thousand square kilometres. Transcarpathian region has two types of relief: mountainous (Ukrainian Carpathians) and flat (Transcarpathian lowland). The mountainous area occupies approximately 4/5 of the area. The ranges of the Carpathian Mountains extend from the northwest to the southeast. The altitude of the Transcarpathian lowland reaches 105-120 m and this tract tilts slightly from the mountain ranges to the Tysa River. The area is rich in minerals; there are deposits of rock salt, brown coal, mercury ore, alum stones, gold, polymetallic ores, tuffs, dolomites, pearl stones, bentonite clays, and the like. There are also large concentrations of mineral water springs here. This area has a moderately continental climate, with short and mild winters in the lowland and warm summers. In January, the temperature reaches from -2 to -3 ° C, in July on average +19 ... + 21 ° C. In the upper part of the area, the temperature in the summer is quite cool: +9 ... +13 ° C in July, the winter lasts a long time and is marked by a relatively low temperature: in January -5 ...- 9 ° C. The amount of precipitation depends on the height and ranges from 642 to 1411 mm.

3. Ivano-Frankivsk region. It is located in the northern part of the state, it occupies the foothills and mountainous parts of the Carpathian Mountains located in Ukraine. The territory is 13.9 thousand km2. The region has three types of relief: the north-eastern part is flat (the surface of the Podillya Upland), the middle part covers the foothills (the Pre-Carpathians), and the south-western part is mountainous (the Ukrainian Carpathians). The Carpathian region has a system of river valleys. About half of the region's territory is occupied by the Carpathian Mountains, in particular the mountainous ranges of the Horhan, the Pokuttya and Bukovyna Carpathians, the Hrynyavy and Chyvchyny Mountains, and Chornohora, where the highest point in Ukraine, Hoverla, is situated. Its height is 2,061 m. The reserves of minerals are represented by oil and natural gas (in the Pre-Carpathian oil and gas region), brown coal, ozocerite, large reserves of sulphur and rock and potassium salt, gypsum, slate, phosphorites, various building materials and mineral water wells . It is an area with a moderately continental climate, mild winters, warm summers in the plains and foothills. The average temperature in January is -4 ...- 4.5 ° C , and in July is from + 18 to + 19.5 ° C. In the mountainous area, the temperature is lower: -6 ° C in January, +16 ° C in July. The precipitation reaches from 600 to 800 mm in the Carpathian region, to 1,400 mm in the mountains.

4. Chernivtsi region. It is located in the western part of the country in the Pre-Carpathian and Eastern Carpathian territory. It covers an area of 8.1 thousand square kilometres. In its south-western part there are the Carpathian Mountains, which are a series of ranges, placed in parallel, up to 1,400 m height.

To the north-east of the Carpathian Mountains, the foothills of the piedmont plain reach out. In the northern part of the territory, the Prut-Dnister riparian line lies along with the Khotyn Hill in its middle part. Here is the highest peak of the Ukrainian plains – Berda Mountain , reaching 515 m in height. There is a system of canyon-like valleys of rivers, ravines and gullies that dissect the local surface. In the western part you can find karst. Natural resources are represented by phosphorites, gypsum, quartz, glauconitic sands, clay, limestone, marble, graphite, and brown coal. There are also supplies of mineral wells and therapeutic mud. The territory is characterised by a moderately continental climate: cool and wet in the summer, moderately cold in winter. In January, in the lowlands the temperature is from -4.8 to -5.0 ° C, in the foothills -4.8 ... -5.5 ° C, in the mountains from -6 to -10 ° C, in July + 18.8 ... + 19.5 ° C, + 16.2 ... + 19.0 ° C, +13 ... +16 ° C , respectively. The rate of precipitation is as follows: 500-600 mm - in the plains, 800-1200 mm - in mountainous areas, precipitation falls mainly in the summer.

The Carpathian region of Ukraine covers an area of 56,607 square kilometers , which corresponds to 9.4% of the territory of the country. The above-mentioned Transcarpathian, Ivano-Frankivsk, Lviv and Chernivtsi regions belong to it. This is justly the "natural pearl" of our country, because its territory includes 22% of the nation's forests, 26% of its nature reserves, 36% of its water resources of river flows, 42% of its exclusive and rare underground mineral water. Despite this, it has its own negative conditions related to the geography of the region: low amount of arable land, poor road and transport capability, frequent adverse hydrological phenomena and climatic conditions that complicate farming. This has ensured that the level of economic development favours the plains at the expense of the mountainous areas. This, in the conditions of an open market system, in turn leads to depopulation tendencies, and poses a risk of the disappearance of the distinctive ethno-cultural system of the mountains (Kravtsiv V.S., 2013). The Carpathian region of Ukraine is significantly exposed

to adverse environmental phenomena, such as threatening and catastrophic floods, soil erosion, surface and underground water pollution , damage caused by strong wind, damage to forests from diseases and pests (Kravtsiv, 2013).

In the Carpathian region, there is a general tendency to reduction of emissions of harmful substances in 2017 compared to 2010. In our opinion, the reason for this is that the scope of production is decreasing, the sources of emissions are eliminated, individual production units have stopped operating, and investments have fallen. All of that leads to the fact that the emissions of the enterprises correspond to the normative ones or are lower than them. However, for the last two years the situation has been worsening (see Figure 3).

Considering this, one can track a small increase in the number of substances that have been emitted into the atmosphere by stationary sources that pollute the air. The increase in the number of such cases was possible due to the main factors of pollution; in particular, we observe similar activity near OJSC "Zakarpathaz" and gas pipelines of UMG "PrykarpattransHaz", which is the Transcarpathian regional linear production organisation for the main gas pipelines. Such incidents depended on the volume of gas pumped by these producers. One of the main causes of emissions into the air is obsolete technical equipment, repairs and prophylactic measures at the stations with compressor equipment.The ineffectiveness of obsolete gas-cleaning systems is obvious at asphalt and concrete production enterprises, in particular, at plants run by the Transcarpathian regional road service and the heating networks of Mukachevo, Berehovo, Vynohradiv, Khust.

Inappropriate equipment is also installed at boiler-houses of the Ministry of Transport and Communications of Ukraine. In recent years, it has been possible to notice a significant increase in the number of vehicles and the number of gas stations, which also substantially pollute the atmosphere (Rehional'na dopovid 'pro stan navkolyshn'oho pryrodnoho sererdovyscha Zakarpats'koi oblasti).

The level of pollution of the atmosphere significantly influences the well-being of city residents, leading to the development of chronic diseases of the cardiovascular, nervous and respiratory systems, worsening of the blood state, development of allergic reactions, etc. Most of all, this is felt by people living near highways which are characterized by heavy traffic. Here the level of contamination is many times higher than the level of harmful emissions in places without such traffic, or in the park zones. Cars have the ability not only to pollute the air, but also to have a negative acoustic effect. According to researchers, noise pollution contributes to the exacerbation of diseases of the cardiovascular system, which causes the bulk of deaths among city residents (Rehional'na dopovid 'pro stan navkolyshn'oho pryrodnoho sererdovyscha u L'vivs'kij oblasti).

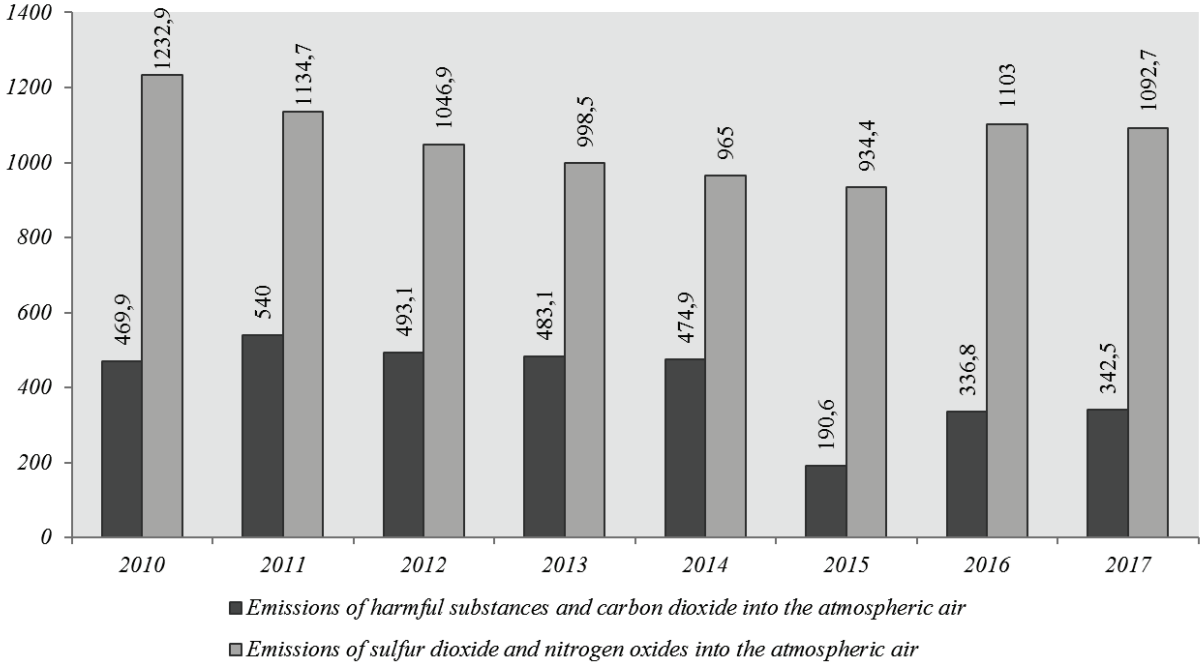

Fig. 3. Dynamics of indicators of emissions of harmful substances into the atmosphere of the Carpathian region during 2010-2017

*- developed by the author on the basis of statistical data of the regions of the Carpathian region

Among the main sources of air pollution in Ivano-Frankivsk region, it is crucial to point out entrepreneurial activity directed at the production and distribution of electricity, gas and water resources (89.2% of total regional scopes). In this context, one should note businesses in the towns of Burshtyn and Kalush, and other settlements of Dolyna, Nadvirna and Bohorodchany districts. To a large extent, harmful effects on atmospheric air are caused by the spread of pollutants from central European countries; regrettably the absence of a network of control points precludes the possibility of an accurate assessment of the extent of transboundary pollution and the scale of its impact on the atmospheric air of the region (Rehional'na dopovid 'pro stan navkolyshn'oho pryrodnoho sererdovyscha v Ivano-Frankivsk region).

In recent years, due to the decline of the production industry and the replacement of solid fuel with gaseous fuel, in Chernivtsi region, it has been possible to observe a slight decrease in the level of pollution of atmospheric air. It is worth mentioning that on the territory of the Chernivtsi region, the choice of modern highly-advanced and economical heating devices is becoming more and more popular among enterprises. Such facilities for heating buildings and providing for other technological needs unconditionally reduce the harmful effects of emissions and help maintain the state of the atmospheric air (Rehional'na dopovid 'pro stan navkolyshn'oho pryrodnoho sererdovyscha v Chernivets'kij oblasti).

Researchers state the fact of the development of compensatory mechanisms for the differences between integrated farms of the regions by a regional political system. These involve the creation of special subsidies and preferential loans, which will stimulate investment activity and its development in regions with an under-developed economy. Thus, lagging regions have a chance to step forward in their development, while modern leading regions may lose this status. It follows that such processes have the chance to gain momentum and require constant state attention. If this is not provided, regions with depressive symptoms may stop their development completely (Hajdenko).

Therefore, realization of the state tasks and goals, i.e. carrying out of economic, social, demographic, scientific and technical and ecological policies on the regional level, has a significant impact on the development of the territorial structure of the economic complex of the region (area, territory). It should be outlined that the influence of regional policy on the development of the economic complex of the region is performed through regional planning, forecasting and programming.

Regarding the economic aspects of the study of the territorial structure of the economic complex of the Carpathian region, their dynamics are determined by the demographic situation of the region, which is characterized by a decrease in the rural population, a decrease in the growth rate of the rural population, its ageing (individuals over 70 years old represent the largest share in the general age structure of the population), emigration of young people, though an increasing birth rate provides a positive tendency (see Table 1). The combination of these facts is confirmed by the fact that there is a gradual extinction of labour resources in this territory and, accordingly, deterioration in the professional training of the existing population. This is explained by the fact that the processes of ageing of the labour force negatively affect the informatisation of all spheres of functioning of the region in connection with the failure of the latter to master the state-of-the-art technologies.

In accordance with the above data, we can conclude that in all regions of the Carpathian region, apart from Lviv, the share of rural population prevails. In particular, the rural population prevails in the population structure of Transcarpathian region and is growing at a higher pace. In general, the population of the region has grown by 1.07%, while the population of such regions as Lviv, Ivano-Frankivsk has decreased by 0.78% and 0.23% respectively, while Chernivtsi it has increased by only 0.25%. Due to this, the population of the Carpathian region has declined by 0.13% since 2010 up to 2018. Regarding the structure, city residents predominate in Lviv region, in Ivano-Frankivsk region there are fewer urban residents, and in Chernivtsi there are also fewer city residents than rural inhabitants. The urban population in Lviv region has decreased by 0.37%, the number of inhabitants of villages - by 1.41%, and in Ivano-Frankivsk and Chernivtsi regions - by 1.66% and 1.69% respectively. This has provided a reduction of the rural population of the Carpathian region by 0.83% from 2010 to 2018.

Such a demographic situation has affected the structure of the labour market, the formation of which is accompanied by the release of a significant amount of labour resources and the deterioration of the situation in occupation and employment. At the same time, the liberalisation of border crossing has contributed to the mass emigration of villagers to neighbouring states with the purpose of employment. This has become a consequence of the economic processes that are taking place in the region, which are high unemployment, predominance of part-time jobs, and low wages.

The general indicator that determines the efficiency of functioning of the region's economy is

Table 1. The dynamics of demographic indicators of the Carpathian region population during 2010-2018, thsd persons*

Indicator	Year									Deviation
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2018-2010 +/-
Transcarpathian Region										
Current Population:	1244.8	1247.4	1250.7	1254.4	1256.9	1259.6	1259.2	1258.8	1258.1	13.3
Urban Population	462.6	463.8	465.2	466.4	466.9	467.3	467	465.5	465.5	2.9
Rural Population	782.2	783.6	785.5	788	790	792.3	792.2	793.3	792.6	10.4
Lviv Region										
Current Population:	2549.6	2544.7	2540.9	2540.7	2538.4	2537.7	2534.2	2534.0	2529.6	-20
Urban Population	1547.9	1546.4	1544.8	1546,1	1545.8	1547.1	1544.9	1544.7	15421	-5.8
Rural Population	1001.6	998.2	996.1	994.5	992.5	990.7	989.3	989.3	987.5	-14.1
Ivano-Frankivsk Region										
Current Population:	1380.7	1379.8	1380.1	1381.8	1382.1	1382.6	1382.4	1379.9	1377.5	-3,2
Urban Population	596.4	597.2	597.7	599.6	600.8	602.6	604.5	605.1	606.2	9.8
Rural Population	784.3	782.6	782.4	782.2	781.3	780	777.9	774.8	771.3	-13
Chernivtsi Region										
Current Population:	904.4	904.3	905.3	907.2	908.5	910	909.9	908.1	906.7	2.3
Urban Population	379.3	381.1	383.1	385.7	388.2	390.3	391.8	391.1	390.5	11.2
Rural Population	525.1	523.2	522.2	521.5	520.3	519.7	518.1	517	516.2	-8.9
Carpathian Region										
Current Population:	6079.5	6076.2	6077	6084.1	6085.9	6089.9	6085.7	6080.8	6071.9	-7.6
Urban Population	2986.2	2988.5	2990.8	2997.8	3001.7	3007.3	3008.2	3006.4	3004.3	18.1
Rural Population	3093.2	3087.6	3086.2	3086.2	3084.1	3082.7	3077.5	3074.4	3067.6	-25.6

**- developed by the author on the basis of statistical data of the regions of the Carpathian region*

the gross regional product, which is defined as the sum of the gross value added of all types of economic activity, including net taxes on products (see Table 2).

The gross regional product of the Carpathian region has been increasing throughout the period of the entire investigation, but this dynamic cannot be called uniquely positive due to the devaluation of the national currency and inflationary processes. At the same time, GRP per capita is increasing, and the growth rate is slowing down with each year. The largest GRP has been produced in the Lviv region, in the second place is Ivano-Frankivsk region, further - Chernivtsi and Transcarpathian regions. This determines the share of GRP per capita in terms of areas. The growth rate of the Transcarpathian GRP has a multi-vector dynamic, but with each year the dynamic is positive. In the Lviv, Ivano-Frankivsk and Chernivtsi regions, there is the same trend of the GRP.

Therefore, the most important measures for the development of the economic complex of the Carpathian region should include the harmonization of the social sphere with the existing needs of the population. The important aspect of development is providing of conditions for the regular reproduction of the labour force through raising the living standards of the population, especially in villages. An equally important condition for achieving such a level of development of the socio-economic potential of the region is the harmonization of development both of society and the natural environment.

Geopolitics of the territory and special ecological conditions have influenced the creation of the territorial structure of the economic complex of the Carpathian region. The territorial structure of the economy of the region combines the location, spatial systems, the apparatus for the development of settlements, the infrastructure of society and production, and the interconnection of all types of economic activity, which has arisen on the basis of natural and mineral resources (Nahirna, 2009).

As we see, the basis of the economic complex of the Carpathian region is the production and distribution of electricity, gas and water - 25.6%. In the context of the development of the processing industry, the main industries are machine-building, chemical and petrochemical industries, as well as

Table 2. The dynamics of the gross regional product of the Carpathian region during 2010-2018*

Indicator	Year									Deviation 2018-2010 +/-
	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Transcarpathian Region										
GRP total, in actual prices, mln. UAH	15299	18054	21404	21400	24120	28952	32390	-	-	-
GRP per capita , in actual prices , UAH	12278	14455	17088	17044	19170	22989	25727	-	-	-
Lviv Region										
GRP total, in actual prices, mln. UAH	41655	52103	61962	63329	72923	94690	114842	-	-	-
GRP per capita, in actual prices, UAH	16353	20490	24387	24937	28731	37338	45319	-	-	-
Ivano-Frankivsk Region										
GRP total, in actual prices, mln. UAH	20446	26752	32286	33196	37643	45854	51404	-	-	-
GRP per capita, in actual prices, UAH	14814	19386	23379	24022	27232	33170	37220	-	-	-
Chernivtsi Region										
GRP total, in actual prices, mln. UAH	9892	11969	13166	13757	15049	18506	21239	-	-	-
GRP per capita, in actual prices, UAH	10939	13228	14529	15154	16552	20338	23365	-	-	-
Carpathian Region										
GRP total, in actual prices, mln. UAH	87292	108878	128818	131682	149735	188002	219875	-	-	-

**- developed by the author on the basis of statistical data of the regions of the Carpathian region*

the woodworking industry. What is more, important areas of development are agriculture, recreation and tourism.

The level of economic growth of all sectors of the economy enables consumer demand to be met and solves economic problems in the region. One of the largest spheres in the public production of the region is industry. The level of its development is an indicator of the economic status of the region, its territorial specialization and the scale of the region's participation in the territorial division of labour. In the process of formation of economic conditions, stipulated by the level of market development, industrial producers are constantly looking for ways to improve and increase the competitiveness of their own production under existing conditions.

The value of industrial products sold in the Carpathian region increased in the 2010-2018 by 164,168,021 thousand UAH, in particular due to the growth of this indicator in all regions. However, the increase in industrial production indexes may indicate an increase in prices for industrial products with a slight increase in the scope of production or supply. In contrast to the overall trend, in the Transcarpathian region, the index of industrial production has declined by 29.1%.

Having analysed a number of economic and geographical areas of the territorial structure of the economic complex of the Carpathian region, in our opinion, it is necessary to emphasize the importance of the problem of the current ecological situation, which is caused by numerous factors.

The main reasons for the deterioration of the ecology of the Carpathian region are the following:

Table 3. Sectoral structure of industry in terms of the regions of the Carpathian region, %*

Industry Sectors	Transcarpathian	Ivano-Frankivsk	Lviv	Chernivtsi	Carpathian region
All industries	100	100	100	100	100
Mining industry: total	1.4	6.5	4.7	1.1	3.4
Including: mining of fuel and energy natural resources	0.1	6.2	4.4	-	2.7
Production and distribution of electricity, gas and water	15.9	35.9	19.0	31.6	25.6
Processing industries in total	82.7	57.6	76.3	67.3	71.0
including metallurgical production	0.6	1.2	4.4	5.8	3.0
Chemical and petrochemical	7.2	9.0	7.8	6.7	7.7
Machine-building	41.4	2.4	11.6	8.6	16.0
Woodworking	4.6	9.2	3.2	3.5	5.1
Cellulose and paper production	1.0	3.0	5.4	1.5	2.7
Manufacture of coke, refined petroleum products	-	6.9	6.9	-	3.5
Consumer goods industry	5.1	2.0	3.3	6.6	4.3
Food industry	15.3	15.3	26.5	25.5	20.7

**- developed by the author on the basis of (Nahirna, 2009)*

Table 4. Dynamics of the value of sold industrial products (goods, services) of the Carpathian region during 2010-2018, ths. UAH*

Indicator	Year									Deviation 2018-2010 +/-
	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Transcarpathian Region										
Value of sold industrial products (goods, services)	7,07 9,125,7	8,86 6,443,7	9,95 6,782,1	10,03 5,856,7	11,15 3,268,7	13,87 2,542,6	184,718,622	22,39 9,848,2	25,23 3,378,1	18,15 4,252
Indices of industrial products	142,9	101,8	101,4	96,9	106,1	79,7	105,9	100,3	101,3	-41,6
Lviv Region										
Value of sold industrial products (goods, services)	25,65 5,264,.9	32,39 2,240,1	34,87 3,983,9	34,62 0,468,3	39,58 4,498,4	58,50 1,981,4	72,385,789,9	91,45 7,271,8	92,87 9,613,2	67,22 4,348
Indices of industrial products	-	-	-	101,2	97,2	98,5	99,3	106,0	103,4	-
Ivano-Frankivsk Region										
Value of sold industrial products (goods, services)	13,83 7,621,1	24,18 7,656,4	25,26 8,815,4	22,01 4,433,7	25,14 2,777,5	34,74 1,880,0	37,267,619,4	48,83 4,881,0	49,91 1,225,7	36,07 3,604
Indices of industrial products	-	-	-	95,3	98,9	89,1	95,5	112,0	107,6	-
Chernivtsi Region										
Value of sold industrial products (goods, services)	3,19 2,600	4,06 7,200	4,10 8,800	4,09 9,700	4,67 6,000	6,82 4,300	9,42 5,542,3	9,68 5,532,1	9,98 1,425,3	6,78 8,825
Indices of industrial products	-	-	-	103,7	92,9	98,3	96,9	106,7	105,5	-
Carpathian Region										
Value of sold industrial products (goods, services)	13,83 7,621	60,11 4,647	70,59 4,699	70,95 4,0	73,89 8,803	90,15 5,647	137,55 0,813	172,37 7,533	178,00 5,642	164,16 8,021
Indices of industrial products	-	-	-	99,275	98,775	91,4	99,4	106,2	104.5	-

**- developed by the author on the basis of statistical data of the regions of the Carpathian region*

the lack of a proper balance between certain economic and industrial sectors, ignorant and unsympathetic attitude to nature and ecology in general. This has led to intensive use of natural resources and deterioration of the state of environment. The latter is closely linked to the influence of pollution factors, which negatively affects the health of the population in general and children in particular. The deteriorating state of ecology plays a significant role in increasing mortality rates. Electricity related substances, concerning the sphere of chemical, mining, as well as the transport and food industries, cause the majority of harmful emissions in the Carpathian region (Maniv, Luts'kyj, Maniv, 2007).

The natural environment is characterized by the states of exhaustion and degradation, which may be caused by insufficient ecological justification of the use of natural resources, the development of new lands and mining, agricultural methods, etc. The same applies to damage to integral landscape surfaces, the ecologically unbalanced structure of agricultural land use, which is aimed at obtaining agricultural products, and frequently ignores the ecological capacity, erosion resistance and excessive ruin of the earth's surface. Other negative factors are unreasonable exploitation of forestry, neglect of the importance of forests for modern ecology (Chakhraiuk- Onofrej, Lakusta, 2011).

The use of water reserves can also be considered as extremely irrational and unprofitable. Moreover, their pollution can be defined by industrial and agricultural wastes. It is worth noting that the greatest damage to surface and underground waters is brought by settlements, farms for breeding animals and various complexes, since they usually do not have sewerage and cleaning systems (Maniv, Luts'kyj, Maniv, 2007).

The Carpathian region is the most dangerous in terms of natural phenomena, in particular, floods. The probability of the occurrence of this natural disaster today has a tendency of growth. Every year flooding damages all regions of the Carpathian region. On this basis, it can be argued that the main method of securing this region is to take measures for soil retention, strengthening dams and other structures, which serve protective functions (Chakhraiuk-Onofrej, Lakusta, 2011).

Consequently, for the Carpathian region, as well as for other regions of Ukraine, there are many problems in the development of economic potential. That is why it is necessary to conduct in-depth studies of the development of all strategically important industries of the region in order to eliminate the downsides and improve the structure of the economic potential of the Carpathian region. The problems of the development of the territorial structure of the economic complex of the Carpathian region include socio-economic, institutional and natural and ecological. However, they all have complex solutions, the implementation of which can eliminate the problem or at least periodically will halt their negative action. At the same time, it is necessary to improve each industry of the manufacturing and non-productive sphere, introducing measures to improve their development, which in general would improve the development of the whole Carpathian region.

When we take into account the available and favourable natural, economic, scientific and technical factors in the development of the economic complex in the region, its historical and geographical heritage, strategic goals should include three aspects:

- reasonable use of natural, material and technical, labour and intellectual potentials;
- creation of an effective economic system, which is able to provide for the material needs of various industries of the territorial economy;
- increase the level of environmental safety in the region.

Herewith, based on the received data on the socio-economic and ecological status, there are some main priorities to develop the Carpathian region. These priorities are as follows:

- development of tourist and recreational, agricultural and industrial, and forestry complexes; development of the non-productive sphere (especially in the mountainous territories);
- increase the economic development of the Carpathian region;
- protecting the environment;
- raising the responsibility for the irrational use of natural resources and large amounts of pollutant emissions into the environment ;
- taking measures to restore historical and cultural traditions of the Carpathian region.

Conclusion. Summing up all of the above mentioned, we can conclude that the development of the economic complex in the Carpathian region depends on its natural and economic potential. Awareness of the significance of the development of the economic complex at the present stage of the socio-economic transformation of the economic mechanism which is taking place in our country, is the best way to improve the standard of living of the population. Emphasising the importance of the economic complex, it should be noted that it involves a variety of directions of development of market relations in our country, the study and implementation of which covers the widest

range of problems, the solution of which is a priority task on the way to restructuring the socio-economic mechanism of functioning of the Ukrainian economy.

Increasing the level of development of the economic complex will help in solving the problems of employment, structural changes in the economy, the formation of a competitive environment and the middle class of owners, which would guarantee stability and democracy in the society. Therefore, it will be crucial to study the potential to ensure the wise use of the investment climate, social processes, and, as a consequence, raise the standard of living of the population of Ukraine.

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Structural organization of sacred landscapes

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Abstract. The article presents the results of scientific developments concerning the structural organization of sacred landscapes. The methodological basis of the study is the concept of constructive-geographic analysis, which is based on the approaches of the natural and the humanitarian sciences. The system approach to the study of sacred landscapes as a holistic organized territorial structure and a set of methods is used in this work, in particular: structural and logical generalization and system analysis, comparative and geographical, historical and geographical. The author considers the significance of the notion of sacral landscape as being broader than religion per se, and considers it a natural, natural-anthropogenic and anthropogenic system associated with certain symbols of life, myths, significant events, and , indeed ,religious feelings that are of great importance to a person or group of people and requires special respect and protection. The structural organization of all sacred landscapes is characterized by their properties and spatial structure and is closely connected with their social and functional purpose. As a result, such territorial systems can be divided into: confessional, taphal, active, abnormal. The sacred landscape is characterized by polystructurality, that is, the presence of spatial, temporal and morphological structure. In the spatial structure of the sacral landscape, the following components can be distinguished: the sacred object, anthropogenic and technogenic component, the landscape structure and a person with his/her spiritual experience. In addition, such a structure has a hierarchical construction, where individual, local, regional, national and global levels can be distinguished. This article presents the peculiarities of the temporal structure of sacral landscapes and outlines the external, internal, and the functioning time. Particular attention is paid to the characteristic of internal time, where one can distinguish the following phases of development: the formation of a natural, natural-anthropogenic or anthropogenic landscape; the creation of a spiritual component; loss of sacred human perception of a natural, natural-anthropogenic or anthropogenic landscape; the disappearance of the natural or natural- anthropogenic landscape. Taking into account the morphological structure of the sacred landscape, it is substantiated that religious objects serving as markers of sacred landscapes cannot correspond to one or another morphological unit of the landscape, that is, completely repeat its outlines and boundaries. However, there is a correlation between the type of landscape and the features of the sacred objects that were formed there.

Keywords: sacred landscape, sacred object, structure, structural organization of the landscape.

Структурна організація сакральних ландшафтів

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Анотація. В статті розглянуто зміст поняття структурна організація в контексті вивчення сакральних ландшафтів, а також розширено понятійне поле дефініції «сакральний ландшафт», що сприяє узагальненню поглядів представників різних наукових шкіл, які досліджували категорію “сакральний”. Сакральний ландшафт розглядається з позицій маркованої географічної системи, яка сформована духовним досвідом людини, який за своєю суттю є ширшим ніж релігійний досвід. Структурна організація усіх сакральних ландшафтів має різне суспільно-функціональним призначенням, тому й відрізняється просторовою структурою. Відповідно такі територіальні системи можна поділити на: конфесійні, тафальні, діяльнісні, аномальні. В межах сакрального ландшафту виявлено й охарактеризовано просторову, часову, морфологічну структури. З’ясовано, що просторова структура досліджуваних територіальних систем має ієрархічну будову, де можна виокремити індивідуальний, локальний, регіональний, національний, глобальні рівні й поділяється на такі складові: сакральний об’єкт, антропогенно-техногенна складова, ландшафтна структура, людина з її духовним досвідом. Обґрунтовано особливості часової структури сакральних ландшафтів й виокремлено зовнішній, внутрішній та час функціонування. Автором доведено, що культові об’єкти,

які слугують маркерами сакрального ландшафту не можуть відповідати тій чи іншій морфологічній одиниці ландшафту, тобто повністю повторювати її контури та межі. Проте, існує взаємозалежність між типом ландшафтної місцевості і особливостями сформованого в її межах сакрального об'єкту.

Ключові слова: сакральний ландшафт, сакральний об'єкт, структура, структурна організація ландшафту.

Introduction. A sacred landscape has signs of a complex system characterized by a territorial organization, polystructurality, nonlinear interaction of components and spatial heterogeneity.

The complexity of landscapes should be distinguished from landscape heterogeneity: complexity is a state of orderliness and chaos with well-separated structures (Papadimitriou, 2010). Therefore, in geographic science, the random distribution model of spatial elements is used to assess the complexity of the logical spatial organization of real landscapes (Cushman et al., 2012; Turner, Gardner, 2015).

The founder of the scientific study of the phenomenon of "organization" can be considered A. Bogdanov (1925), who elaborated the complete idea of organizational science, formulated its main principles and laws, explained the mechanisms of manifestation, presented the role of science in the organization and its significance in the understanding of the universe, and outlined ways of its development.

Problems and questions of the organization of natural and socio-economic systems are covered in the works of A. Topchiev (1988), L. Leskov (2005), B. Mil'ner (2005). Among landscape experts it is necessary to distinguish the work of V. Preobrazhenskij (1986) "Organization, organization of the landscape".

The structural organization of territorial systems is an ordered distribution of their components in general, a means of their interconnection, co-subordination, the nature of the hierarchy (Petlin, 2016).

The structural organization of the landscape serves as an indicator of landscape-forming processes. It is the totality of the structures of the landscape, and the corresponding links characterize the territorial system, their functional purpose and organizational capabilities.

The sacred landscape is considered by us as a natural, natural-anthropogenic, anthropogenic system, associated with certain life symbols, myths, important events, religious feelings, is extremely valuable to a person or group of people and needs special respect and protection (Mishchenko, 2018).

Sacred landscape is an extremely interesting and relevant research object, which includes in its composition territorial systems of different genesis, a person, his/her spiritual perception of these systems. The need to identify the types of structures of the sacred landscape and their characteristics, which determines the degree of its complexity and organization, led to the choice of the topic of scientific work.

Materials and methods. The methodological basis of the study is the concept of constructive-geographic analysis, which is based on the approaches of the natural sciences and the humanities. The paper uses a systematic approach to the study of sacred landscapes as a holistic organized territorial system and a set of methods, in particular:

– structural and logical generalization and system analysis, which are used for study and generalization of theoretical approaches to the definition of concepts of structure, structural organization of territorial systems;

– comparative and geographical, which was used for the purpose of determining the morphological structures of sacred landscapes in the conditions of the Volyn Polissya;

– historical and geographical, which was used to study the historical and geographical features of the formation of sacred landscapes.

Results and their analysis. A structure is a description of the composition and a spatial picture of the composition of an object, matter, the interplacement of formations, parts, details, elements, a certain functional interconnection of the components of the object, and the internal structure (Velykyi tlumachnyi slovnyk suchasnoi ukrainskoi movy, 2005). The structure contains the composition of subordinate systems, their mutual arrangement (spatial, or morphological structure) and the various interactions between them (functional structure), all in dynamics, variability, and space and time (Mazing, 1973); structure is a generalized characteristic of specific system properties that captures the elements, relations, system connections, and their organization in an abstract form (Sadovskij, 1974).

Any geographical construct is structured according to a particular structural scheme. The simplest such scheme is the conditional graphic (mathematical, etc.) of the elements of the system and the links between them (Nechiporenko, 1977). The structure of a natural and territorial system is considered as a changeable system order in the form of an invariant entity of the organization, which consists of mechanisms of its spatio-temporal functioning, internal components and internally emergent

components as a manifestation of integrity (Petlin, 2006). Spatially complex combinations of indigenous and conventionally indigenous components with derivatives created by man as components of the environment as anthropogenized structure are considered (Ivanov, 2007).

The scheme of classification of structures of the geographical system distinguishes the following main types:

– spatial, in particular vertical (topical), territorial (choral);

– time, in particular, functional and ethological (Samoilenko, 2003).

The configuration of a sacred landscape has a spotted structure and the background of it is landscape complexes with the usual sacred level and "the nuclei" are the places with an increased number of foci (especially sacred) (Hrodzynskyi, 2005). In the case of ethnocultural analysis of sacral landscapes, the spotted structure will be multilayered, where "nuclei" may overlap (sometimes completely) or not at all. For each ethnic group inhabiting the corresponding ethno-cultural landscape, sacral nuclei will be different places or objects. Moreover, the Ukrainian sacred landscape will be profane for the Jewish or Polish ethnos (*Volovyk*, 2013; Denysyk, 2014). *Volovyk* (2013) has built a sacred landscape model for a monoethnic and polyethnic landscape. Such a model corresponds to the idea of "sacred centroperiphery", where in the landscape live the community, subordinated to the one true God with the corresponding unique sacral order (Kizima, 2003). However, the sacred landscape encompasses not only religious systems (Mishchenko, 2018). Since the process of sacralization is conditioned by the provision of natural, natural and anthropogenic objects with unusual properties (sacred content), the sacred landscape is interpreted as a symbolically marked geographical system, formed by the spiritual experience of a person, which in its essence is wider than religious experience alone.

The structural organization of any sacral landscape is characterized by its properties and spatial structure and is closely connected with their social and functional purpose. Accordingly, such territorial systems can be divided into: confessional, which are related with the peculiarities of religious belief within a certain religious doctrine;

– taphal, which are modern and ancient places of burial;

– active, which are territorial systems, connected with a certain event, which is important, sacred, religious curative, meaningful;

– abnormal, which are territorial systems of sacredness, the special significance of which are manifested through deviations from the norm or from the average value of physico-geographical, biogeochemical or other indicators.

Undoubtedly, in practice, the same sacred landscapes can have different functional purposes. For example, a number of sacred springs which are located within the Volyn region are sanctified by representatives of Christian institutions. In addition, such objects may be associated with a particular event: the appearance of a "miracle" (church objects, or saints), healing from an illness. The water in the springs has somewhat abnormal characteristics: low temperature values, high transparency, high content of silver**.**

N. Lavrinova (2015) has constructed a systemic model of a geographic landscape, in the structure of which are allocated natural and geocultural subsystems. The sacred landscape in this model serves as an inalienable part of integrating the subsystems into a single geospatial space. The history of the formation of the selected elements in this model is divided into periods that can be considered as structural parts of the sacred landscape, in particular:

– formation of a natural basis;

– formation of ethnic basis;

– the creation of cultural complexes, which are elements of the superstructure that define and characterize the cultural content of the territorial system. The ingredients of such complexes are ideology, politics, religion, culture, actions, customs, feelings.

The sacred landscape is a complex system in which not only the natural and anthropogenic components, but also the spiritual, interact .This entails the transfer of the national heritage from generation to generation of the, that is, objects of cultural heritage that can have a natural, natural- anthropogenic or anthropogenic origin. In this regard, one can speak of the integrity and structure of the spatial organization of the sacred landscape, since it contains natural and cultural elements.

The investigated sacred landscapes are characterized by variability and genetic differentiation. Such territorial systems are not formed in isolated space, but in the structure of already existing natural, natural-man-made or anthropogenic landscapes, the spatial organization of which is determined by their properties and the nature of internal communications. Accordingly, the structure of natural landscapes is a combination of the most stable links between the constituent parts of the system, which were formed in

the process of evolution.

The structure of the natural-human-made landscape is determined by a set of the most stable anthropogenically modified connections between the structural components of the system and individual anthropogenic elements.

Landscapes of anthropogenic origin are characterized by a structure determined by a set of relatively stable and unstable anthropogenically controlled and anthropogenically modified connections between the structural components of the anthropogenic system, which were formed in the process of qualitative transformation of natural and natural anthropogenic landscapes (Petlin, 2009). The functioning of sacred landscapes is ensured by the continuous transformation of matter, energy, information within the system, as well as between different systems. Such processes point to the existence of material-energy, information and interconnection links.

The sacral landscape is characterized by polystructure, that is, the presence of spatial, temporal, morphological structure on figure 1.

The spatial structure of the investigated territorial systems is characterized by spatial correlation and consistency of internal parts. Such a structure has anthropogenic origin. However, within a single sacred landscape there may be several religious (holy) objects. For example, within the limits of temple and monastic complexes, several sacred objects are typically recorded, in particular: the church itself, a burial place, a sacred spring in the courtyard of the church. The unifying characteristic of such objects is their spiritual perception by man. Such polyobjectivity is characterized by a hierarchy and determines the integrity of the sacred landscape. With the development of society, the sacred value of the holy object is changing. This is due to the logical changes in ideology, culture, and religious inquiry, which results in changes not only in the landscape itself, but also in its function, and therefore the structural organization.

The landscape structure consists of an eminently integral interaction of differentiated systemic entities formed as a result of the regular development of territorial unities. Within it, it is possible to distinguish between abiotic natural components that cover the hydrogeological, geomorphological, microclimatic features of the sacred landscape, as well as the flora and fauna that formed within it.

The anthropo-technogenic component is determined by a certain infrastructural maintenance

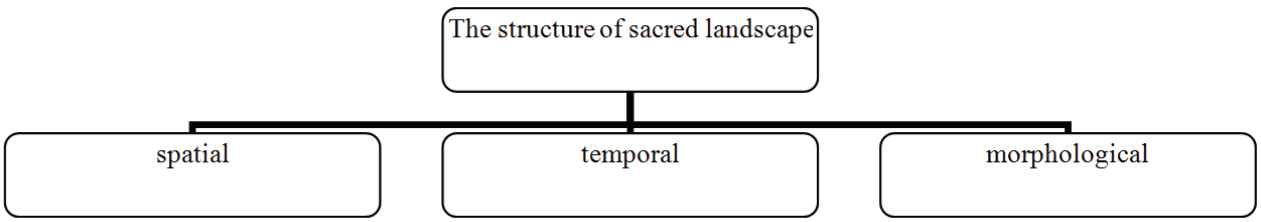

Fig. 1. Structures of the sacred landscape

signs of systemicity, orderliness, and interconnections. Within the spatial structure of the sacred landscape, one can distinguish the following components: a sacral object, an anthropogenic and man-made component, a landscape structure, a spiritual component, a person, as shown in Figure 2.

Any sacralization is related to the search for the centre, therefore the spatial structure of the sacred landscape, more often has the form of a monocentric system, which consists of a number of subsystems that are closely interconnected.

The central component of the spatial structure of a sacred landscape is the sacred object, which has a great sacred, cultural, curative, aesthetic, ideological significance for a certain group of people. Such an object can have a natural, natural-anthropogenic, of sacred landscapes, in particular: asphalt covering, church shops, etc.

Man perceives the sacred landscape not as an object for satisfaction of economic needs, but as an object that needs to be worshiped, honoured, and guarded. Instruments of sacralization of such objects are: religious feelings, legends, myths, symbols, historical facts, individual sacred feelings.

The spatial structure of the sacred landscape has a hierarchical structure, where individual, local, regional, national, global levels can be distinguished (Mishchenko, 2018). The existence of a hierarchy of sacral places is due to their differing degrees of attractive force. The larger the radius of attraction, the higher the hierarchical level is the sacred landscape (Hrodzynskyi, 2005). For example, for

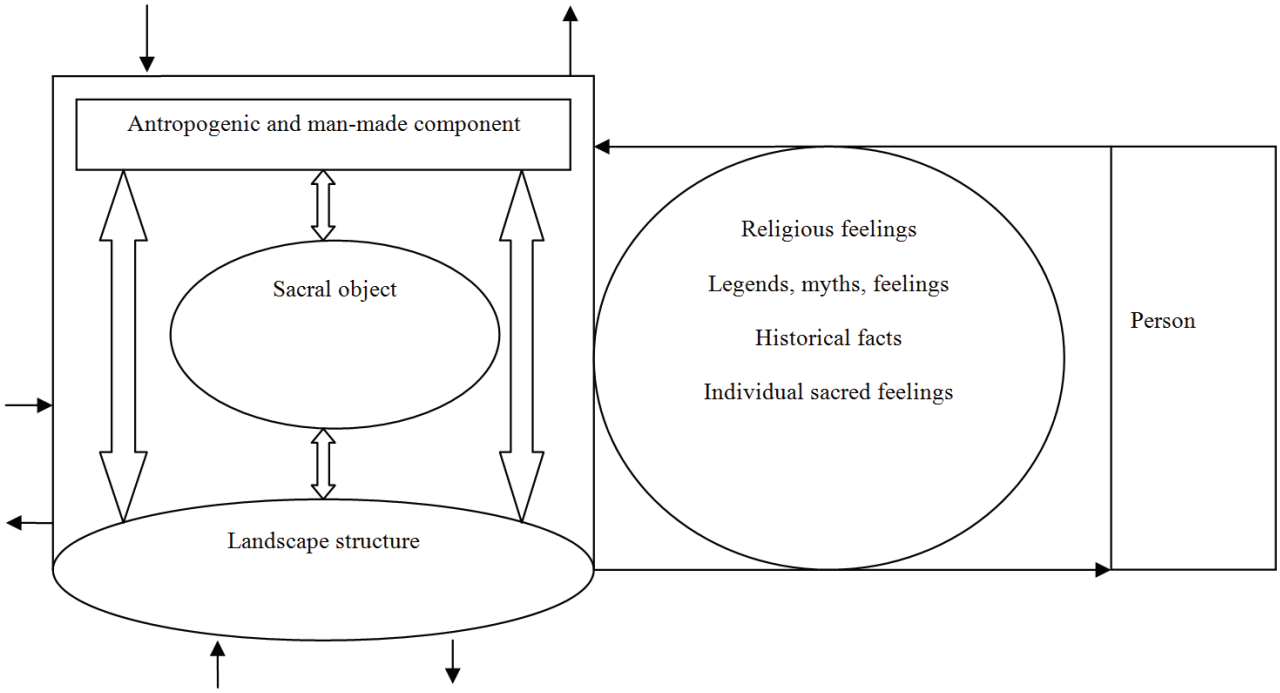

Fig. 2. Spatial structure of the sacred landscape NOTE antropogenic must be anthropogenic

all Christians, Jerusalem serves as the sanctuary of global significance. The radius of its attractive force encompasses the entire Christian world, because pilgrimage is made to this place from around the world. Undoubtedly, there are national sacred territories, in particular, Babyn Yar, a tract that is located in the northwestern suburbs of Kiev. This territory became known due to the mass executions, mainly of Jews, carried out during the German occupation in 1941-1943. An object of regional-level pilgrimage is a spring located in the catchment area of the Western Bug River and its right tributaries of the Luga River, near the village of Budyatychi, Ivanychi district, Volyn oblast. This spring became known for its curative properties in 1637. According to legend, the water of this spring healed people with various ailments. Now a well was built at this site, and a chapel next to it. People from different regions of Ukraine and from abroad come to the sacred spring. By contrast , the congregation of a village church has only to cover a small distance to reach their shared sacral object of local level. However, every person can have his own sacred landscape, which is formed by religious, ideological, cultural, aesthetic and other beliefs.

Time structure of the sacred landscape is determined by a certain change in the states of the system, which manifests itself in the form of seasonal rhythm and long-term restructuring of their relationships. The time structure of any landscape system is characterized by time duality, the content of which depends mainly on the specific features of a certain landscape system and the structural features of its background time (Petlin, 2009). The background time covers not only the existence time of the object (full time), but also the previous and future time. It characterizes the period of the emergence of the landscape's integrity, its development and destruction or transformation into a new integrity (Bokov, 2005). The definition of the background time of the landscape covers the characteristics of the features of its structure in certain periods of operation: the past, present and future.

The time in the landscape exists in three forms, in particular: external, internal and operating time (Bagrov et al., 2005).

The external time is characterized by the rhythm and cyclic nature of the physical and geographical processes occurring in the landscape. In general, time is determined by using different scales. At external time, the scale fixes the rhythmic natural processes that change the state of the landscape during the year or days. These processes are dynamic, and do not lead to the restructuring of the internal structure of the territorial system.

The internal time of the landscape is determined through a consistent, but not regular, arrhythmic change in its states. For the internal time of the territorial system, we can use the scale of the phases of its development. Landscape studies use the scale

of states according to the age of the landscape, or its components, in particular: origin, youth, maturity, old age, death. Consequently, each phase has a different length of time. Considering this question, B. Polynov (1953) found that in each landscape there are different age elements: relict, conservative and progressive. Relict elements so old that tracts that are formed within them characterize the previous history of the landscape. To the category relict belong glacial relief forms, dry riverbeds. Conservative elements are in full compliance with modern natural conditions. Progressive elements indicate the ongoing trends of the landscape and reflect the possible changes. In the context of this issue, I. Mamaj (1982) proposes to distinguish three main phases of the development of landscapes: origin and formation; sustainable existence and slow development; atrophy. The development of the territorial system is conditioned by the gradual quantitative accumulation of elements of the new structure and displacement of the elements of the old structure, which in turn leads to qualitative changes within the landscape.

The internal time of sacred landscapes can be characterized by the following phases of development:

– formation of a natural, natural-anthropogenic, or anthropogenic landscape;

– creation of a spiritual component that determines the formation of the landscape's sacred value by people, that is, the sacred perception of the territorial system;

– loss of a person's sacred perception of a natural, natural-man-made or anthropogenic landscape, due to a change in ideology, political situation, culture, traditions, religious feelings;

– the disappearance of a natural, natural-man-made, anthropogenic landscape.

In landscape studies, it is extremely important to study not only its genesis and age but also spatial and functional relationships (Solncev, 1982). For a landscape , time does not pass until it is in a quasi-stable state. When transitioning to another state, the system is characterized by active functioning until it comes to a new quasi-stable state (Bagrov et al., 2005).

The sacred landscape is within the boundaries of the morphological structure of the landscape, that is, it is an integral part of the facies, tracts, terrain. *Morphological structure of the landscape* is such a correlation of components and the nature of the relationship between them which makes it possible to form interconnected hierarchical structures of the landscape (Petlin, 2018). The morphological structure is characterized by hierarchy, that is, functionally-ordered arrangement of structural parts of the geographical landscape from the lower to the higher, from the facies to the landscape terrain. Any morphological structure of the landscape due to the connections and corresponding functional processes of water exchange, mineral metabolism, gas exchange, energy exchange, biogenic circulation can develop and complicate. It should be taken into consideration that pure interactions within a single morphological pyramid do not exist, since each level interacts with the surrounding natural systems that belong to other neighbouring morphological levels of the hierarchy (Petlin, 2016).

Cult objects that serve as components and markers of sacred landscapes cannot fully correspond to one or another morphological unit of the landscape. For example, a chapel, a water source, separate burials can not be facies, or more than the morphological unit of the landscape, that is, fully corresponding to its contours and boundaries. Sacral objects are only components of one or another morphological unit of the natural, natural- anthropogenic, anthropogenic landscape. However, the pattern of structural organization of the morphological components of the territorial system, which is due to the interdependence between the type of landscape terrain and the peculiarities of the sacral object formed within it, is traced.

Consider the system of morphological structures of sacred landscapes on the example of the physical and geographical area of the Volyn Polissya shown in Figure 3.

According to the physical and geographical conditions within the Volyn Polissya, it is possible to distinguish the following types of landscaped terrain: floodplain and valleys of drainage, floodplain terraced, sloping, interfluve, plakor (flat or gently sloping, well drained area). Almost all types of locality can be distinguished by the following types of sacred tracts: water areas, dendrological sites, temple and monastic complexes, funeral complexes.

Drainage of water areas has in its composition water sources, which are formed within the limits of the natural outlet of groundwater on the earth's surface where the aquifer crosses the earth's surface, that is, in the reliefs' depression, on the slopes of ravines, gulleys, etc. Water sources of the Volyn Polissya are most often formed in the river valleys , gullies, ravines, that is, fed by upper sources of flow due to the physical and geographical features of this territory. Often, such landscapes occur within floodplain areas, and in the structure of sacred landscapes are used not only to meet economic needs, but as objects that need to be worshiped, honoured and protected.

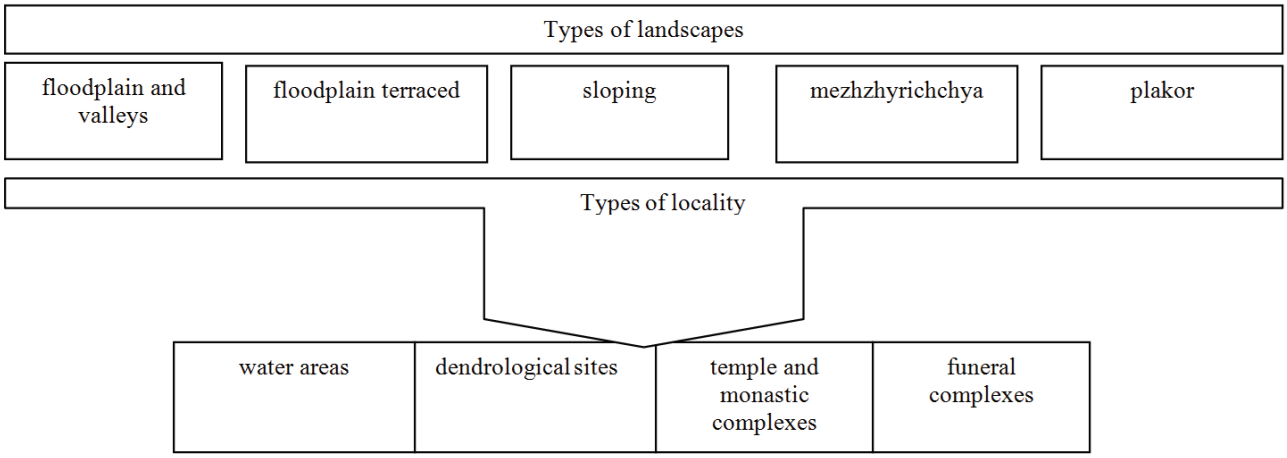

Fig. 3. System of morphological structures of sacred landscapes in conditions of Volyn Polissya. (Type of sacred tracts is determined by the nature of the sacred place)

The taphal landscapes represented by burial complexes can predominantly be formed within the plain and interfluve landscape, as the territory of such areas should not be subjected to landslides or landslips. In addition, geomorphological, geological, hydrogeological conditions and sanitary requirements do not contribute to the construction and formation of burial complexes in river floodplains.

The high hypsometric position of the temple and monastic complexes indicates their spiritual purpose and testifies to the supremacy of the sacred (Denysyk, 2014). Such complexes are mainly built on elevated areas, in particular in plakor, above floodplain terraces, interfluve types of landscape terrain.

Dendrological sites are represented by single trees, as well as sacred groves, can be formed in all of these types of landscaped terrain.

Consequently, there is a natural interdependence between the types of sacred tracts and the terrain in which they are formed. Such compatibility is conditioned by physical and geographical and aesthetic characteristics, environmental norms of the formation of a cult object, its social and functional purpose and confessional demands of society.

Conclusion. The studies of the structural organization of sacred landscapes testify that such territorial systems have in their structure a spiritual component that is connected with life symbols, myths, significant events, religious feelings. The tools of sacralization of the landscape are formed by the spiritual experience of a person, which in its essence is wider than the purely religious.

The social and functional purpose of a sacral landscape clearly forms its structure and organizational capabilities. This article describes the structures of sacred landscapes, in particular: spatial, temporal, morphological.

Within the spatial structure of the sacred landscape, the following components are distinguished: the actual sacral object, the anthropogenic and man-made component, the landscape structure, the person with his/her spiritual experience.

This work describes the temporal forms of the sacred landscape. Particular attention is paid to the internal time, where the phases of development of the investigated territorial systems are distinguished.

Cult objects that serve as an inalienable attribute of sacred landscapes and ensure their integrity cannot fully correspond to one or another morphological unit of the landscape, that is, repeat their outlines and boundaries. However, there is a correlation between the type of landscape terrain and the features of sacred objects.

This research deals with the structural organization of sacred landscapes in general. However, depending on the functional purpose, the phase of development, other features of the organizational structure of the landscape will change. The study of the structural organization of taphal landscapes will be the goal of our further research.

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On different types, conditions, and factors of landslide risks in the city of Dnipro

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Abstract. The paper represents the research results as for the factors of such dangerous geological phenomenon as landslides in terms of geological medium of the city of Dnipro. It is emphasized that there are certain geological, geomorphological, and hydrogeological conditions favouring the development of a medium for landslide formation. Irrespective of long-term study of that phenomenon, spatiotemporal prognosis is a complex scientific problem requiring application of innovative ideas and scientific statements concerning both separate components of a geological medium and rather complex natural and technogenic system. The paper analyzes conditions of the development of deep landslides within the territory of the city of Dnipro connected with a geological structure in a scope going beyond traditional scope of engineering and geological studies. Despite wide occurrence of landslide developments within the territory of the region, landslide of the Dnipro region are not singled out as a separate regional type. According to different estimations, general number of landslides is more than 144 within the city of Dnipro. The studies are based on numerous calculations of slope stability indicating the importance of the occurrence of Pre-Quaternary deposits as the factor favouring deep landslide formations. Basing upon the processing of the geological studies, cartographic modeling of the surfaces of certain levels, their thickness, and analysis of landslides grouping within the areas of singled-out territories have been performed. Maps of the surfaces of reddish-brown (N_2-Q_1) and grey-green (N_1-S_2) clays as well as deposits of Obukhivska (P_2ob) and Mezhyhirska (P_3 mž) suites, representing together the rock thickness corresponding to Kharkiv Stage (P_{2-3}hr), have been developed. It has been proved that occurrence mode of clays at the base of loessial soils creates certain conditions for the development of landslides being different in their mechanisms (i.e. cutting, slipping, and squeezing). An example of certain calculations of slope stability is given confirming the important role of argillaceous rocks in the formation of the zone of changed soil condition and property. It has been proved that occurrence mode of the rocks occurring lower than the depth of water erosion development should be studied thoroughly while designing landslide protection structures to obtain accurate model of the geological medium.

Keywords: landslide, clays, spatial model

Про типи, умови та фактори розвитку зсувних процесів у м Дніпро

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Анотація. В статті наведені результати встановлення регіональних факторів розвитку небезпечних геологічних явищ – зсувів на прикладі геологічного середовища м. Дніпро. До умов розвитку зсувів відносять геологічні, геоморфологічні, гідрогеологічні умови, які створюють середовище виникнення небезпечного явища. Незважаючи на тривале вивчення цього явища, просторово-часовий прогноз є складною науковою проблемою, що потребує застосування нових уявлень та наукових положень як про окремі компоненти геологічного середовища, так й про складну природно-техногенну систему. В даному досліджені розглянути умови розвитку глибоких зсувів на території міста Дніпро, які пов'язані з геологічною будовою у об'ємі, що перебільшує традиційний об'єм інженерно-геологічних досліджень. Незважаючи на широку поширеність зсувних явищ на території регіону, зсуви Дніпровського регіону не виділені як самостійний регіональний тип. Загальна чисельність зсувних явищ за різними оцінками складає понад 144 у межах міста Дніпро. Підставою для дослідження є результати багато чисельних розрахунків стійкості схилів, які вказують на важливу роль залягання до четвертинних відкладів як чинника, що сприяє формуванню глибоких зсувів. На підставі обробки матеріалів геологічних досліджень виконане картографічне моделювання поверхонь окремих горизонтів, їх потужності та аналіз групування зсувних явищ у межах виділених ділянок.

Створені карти поверхонь червоно-бурих глин (N_2-Q_1) та сіро-зелених глин (N_1-S_2), також відкладів обухівський (P2ob) та межигірський (P_3 mž) світ, які в сукупності представляють собою товщу порід, яка відповідає харківському "ярусу" (P2-3hr). Доведено, що умови залягання глин у основи лесових ґрунтів створює умови щодо розвитку зсувів різних за механізмами, а саме: зрізу, ковзання та роздавлювання. Наведений приклад певних розрахунків стійкості схилу, що підтверджують важливу роль глинястих порід у формуванні зони зміненого стану та властивостей ґрунтів. Доведено, що умови залягання гірських порід, що залягають нижче глибини розвитку водної ерозії, необхідно вивчати при розробці протизсувних споруд з метою створення точної моделі геологічного середовища.

Ключові слова: зсув, глини, просторова модель.

Introduction. Research of landslide developments is rather topical current scientific problem. Landslide process along with its accompanying conditions and factors has been already analyzed for a long time. That catastrophic natural and technogenic phenomenon results in considerable economic losses in the countries with rather high scientific achievements (Hirota, Konagai, Sassa, et al., 2019; Wooten, Witt, Miniat, Hales, Aldred, 2016). In terms of the countries with lower level of economic development, dangerous natural and, especially, geological processes cause a problem, which is not considered in time. Current studies of landslide developments are aimed at the solution of certain complex problems. Necessity of searching for innovative methods to analyze landslides and elaboration of scientific methods to prognosticate those phenomena were discussed at the international congress (Alcántara-Ayala, Sassa, Mikoš, et al., 2017). Landslides are studied at different levels from regional to local ones (H. Hong, Chong Xu, Dieu Tien, 2015; A. Ciampalini et al., 2016). Factors and conditions for the development of landslides in different regions are analyzed basing upon the innovative research methods (Choi, Raymond Cheung, 2018). Great attention is paid to the search for new techniques for regional prognosis of landslide developments (Iversona et al., 2015; Reichenbacha et al., 2018) involving neural network methodology as well (Le et al., 2018). New methods of spatiotemporal prognosis of landslides are being developed (Liao, et al., 2011; Reichenbacha et al., 2018). A problem concerning development of new devices to monitor dangerous processes is also rather topical (Jinesh Mehta, et al., 2017.). Gariano, Guzzetti (2016) have emphasized considerable effect of global warming upon the intensity of landslides all over the world. Thus, review of current studies of landslides worldwide demonstrates the necessity of the determining certain regularities in the formation of landslides as a regional dangerous phenomenon with the application of innovative ideas concerning specific geological environment.

Materials and methods. Landslide phenomena are well developed on the territory of Ukraine (Demchishin, 1982; Rud'ko, 2006). Research of the landslides within the territory of Dnipro city began in the 1930s. First notes on the available landslides are found in the materials of engineering and geological studies of the slopes of Zustrichna ravine due to the construction operations. In the 1960s, engineering survey was performed along with the systematic descriptions of landslide processes. Considerable advance of landslides as well as the diversity of their forms and types was highlighted. Surface and deep flow slides, suffusion processes, and slips were identified. In the 1970s, a map of engineering and geological zoning was elaborated; monitoring of erosion and landslide developments within the ravines was completed. In the 1980s-90s, geological processes within the city area were monitored; cadastre of landslides was developed. Within the period of 2000-2014, experts of *PivdenUkrheolohiia* PC and other specialists carried out specific studies of landslide developments.

Despite wide occurrence of landslide developments within the territory of the region (Fig.1), landslides of the Dnipro region were not singled out as the specific regional type.

Features of geological structure, geomorphological, and hydrogeological factors are traditional issues favouring the development of landslides. Technogenic factors also belong to the mentioned ones. According to the geological studies (Nekriach, Maniuk,, 2004), it is known that geological profile of the Dnipro region is represented by the formations of the Archean and Cainozoic erathems. The structure unites rocks of different age (from the Precambrian to Quarternary ones). Deposits of the Quaternary system convers all the territory like a blanket occurring on the sedimentary deposits of the Neogene, Paleogene, and crystalline formations. The geological structure contains separate levels of silty-clayed composition, which may be the medium for the development of landslide processes.

We have analyzed the mode of loessial thickness occurrence during the development of cartographic models of the probability of subsidental deformations (Mokrytska, et al., 2016). According to the features of granulometric composition, conditions, and properties, those levels may be a medium for the development of such natural and technogenic processes as:

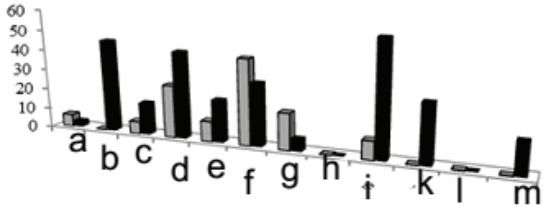

Fig. 1. Occurrence of landslide developments within the erosion systems of the Dnipropetrovsk region (1993).
Notes:

- Landslide developments; - Ravines.

a – River of Dnipro; b - River of Mokra Sura I; c - River of Sukha Sura; d - River of Mokra Sura II; e - River of Samotkan; f - River of Domotkan; g - River of Bezymiannaia; h - River of Kamenka; i - River of Saksahan; k - River of Bazavluk; l - River of Solionaia; m - River of Kamyshevataia Sura.

subsidence, subsidence deterioration, erosion, suffusion, and landslides.

According to the development mechanism, landslides in loessial soils are similar to flows, slides-flows, or suffusion-subsidental landslides. Studies of the features of landslide developments within the region have proved that that phenomenon is characterized by certain staging, manifesting deep landslides at different stages of the slope process development in terms of technogenesis (Mokritskaya, Shestopalov, 2014).

Formation of deep landslides may be connected with the peculiarities of the occurrence of Pre-Quaposits of Obukhivska (***P*$_2$*ob***) and Mezhyhirska (***P*$_3$** mž) suites which represent together a thickness of rocks corresponding to Kharkiv stage (***P*$_{2\text{-}3}$ *hr***). Features of the mode of those deposits occurrence to determine conditions of the formation of deep landslides have not been studied before. The study involves reports on geological research dated back to 1962, 1964-1970, 1970-1974, and 2004. Candidate of Geological Sciences, Maniuk, V.V. helped correlate occurrence of the deposits being different in their origin and age.

Results and their discussions. After thorough study of the archive materials, the obtained data were used as the basis to create a database (Fig. 2) including

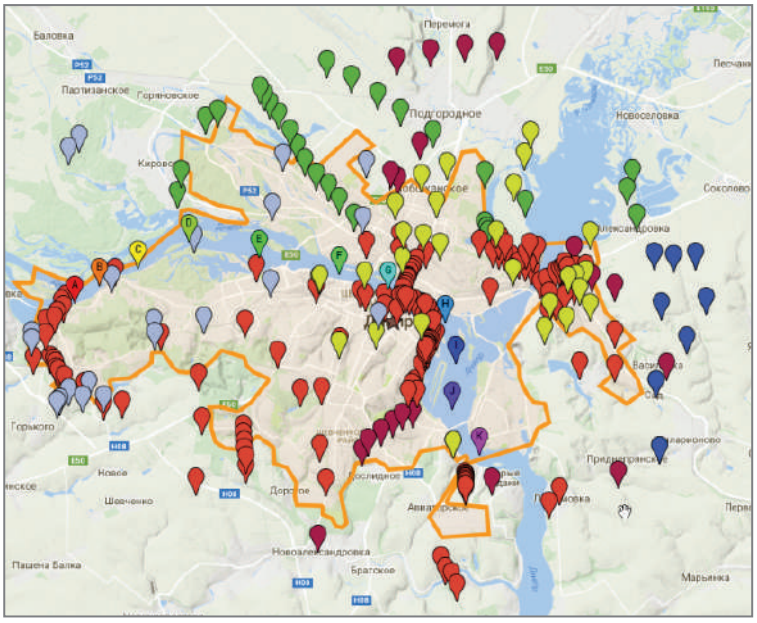

Fig. 2. Location of geological wells within the territory under study

ternary deposits as well. Pre-Quaternary deposits are represented by the abundant deposits of Neogene and Paleogene, i.e. unseparated levels of reddish-brown (N_2-Q_1) and grey-green (N_1-S_2) clays as well as de-

283 wells as well as the information on their location (WGS coordinates), identification number of a well, actual number of a well, stratigraphic indices, absolute elevation, and geological description.

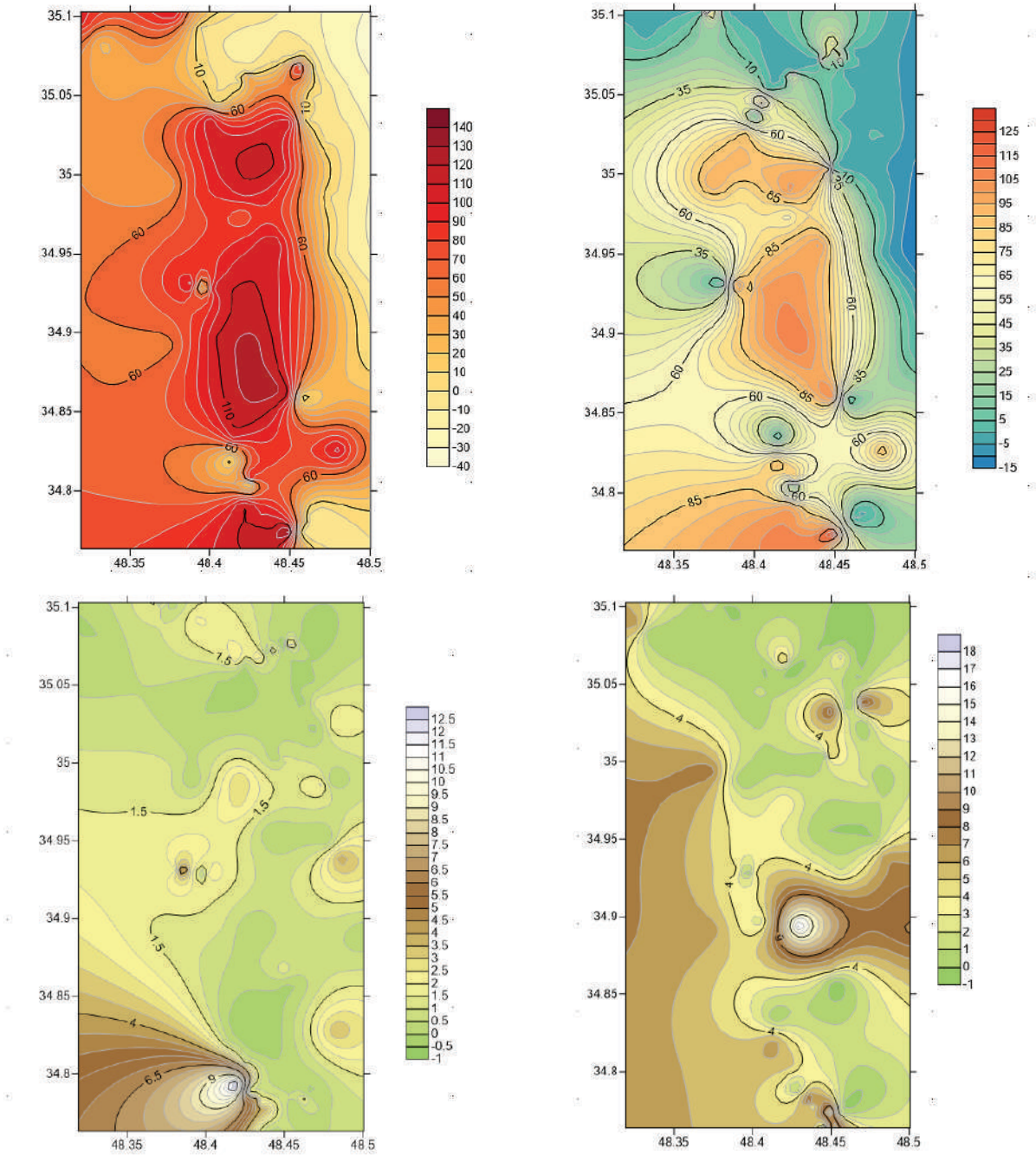

Fig.3. Contour map of the top of reddish-brown (N_2-Q_1) and grey-green (N_1-S_2) clays within the territory of the city of Dnipro and thickness maps (right-bank territory, scale is 1: 50 000).

Demo version of the *Surfer* software was applied to generate a map of surfaces and thicknesses of the indicated levels of the Neogene and Paleogene deposits at a scale of 1:50000 (Fig. 3). Cartographic methods were involved to determine a wash zone of the deposits, to perform overlay mapping, and develop a cartographic model of the mode of the Neogene deposits occurrence within the floor of the Quaternary loessial deposits and the Paleogene deposits within the floor of the Neogene deposits.

Zoning of the territory under study was performed according to the mode of the Neogene deposits occurrence as the factor of landslide developments. Areas corresponding to the wash zones and availability of the Neogene deposits as well as to the areas differing in the surface inclination are separated (Fig.4). Uniting the tops of reddish-brown and green-grey clays into the joint model has made it possible to single out the wash zones of reddish-brown clays (area A). Along with the wash zones, there were highlighted the zones with normal, regular clay occurrence, with almost unchanged thickness (area B), and zones with irregular occurrence (area C), where clay thickness experienced gradual changes, from the considerable

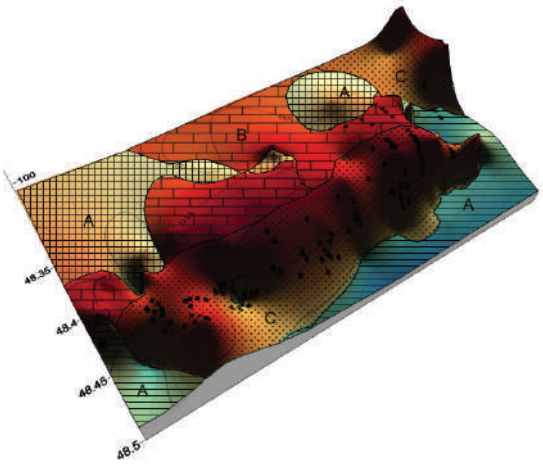

Fig. 4. Zoning map of the city territory in terms of landslide formation within the areas of Neogene clays being different in their occurrence mode.

Legend:
A – wash area of reddish-brown clays within the right-bank territory of the city of Dnipro;
B – zone of regular clay occurrence within the right-bank territory of the city of Dnipro;
C – zone of irregular clay occurrence with changing thickness.
– landslides within the right-bank territory of the city of Dnipro.

to medium-low ones with their following zero value. It is also possible to point out that the angle of soils occurrence is rather steep, more than 5%, which, in case of clay deposits, may be a factor of landslide development in terms of slip type. Following stage of modeling included mapping of the areas of landslide development; generally, 133 areas were identified.

Analysis of the location of landslide development areas shows that there are no landslide developments within the wash zones of the Neogene deposits. Majority of the landslide formation areas is observed within the areas with irregular thickness of the Neogene clay deposits; minority number of those areas is within the zones of the Neogene deposits with regular mode of occurrence. The fact demonstrates that those are the composition, mode of occurrence, and condition of the Neogene deposits which are the factors effecting the development of landslide processes being different in their type. Within the type B areas, formation of the landslide of squeezing type is possible. Within the type C areas, slip landslide is possible.

In terms of the territory under consideration, the Paleogene deposits are available locally. However, since those formations may be considered as silty-clayed ones (in terms of their granulometric composition), and they may demonstrate rheological properties, then regularities of spatial changes in the occurrence mode of Obukhivska (***P*$_2$*ob***) and Mezhyhirska (***P*$_3$** mž) suites have been analyzed (Fig. 5, 6).

The obtained models show incongruence of the regularities of spatial distribution of the deposits of Obukhivska (***P*$_2$*ob***) and Mezhyhirska (***P*$_3$** mž) suites.

Formation of the total surface of the Paleogene deposits roof and superimposing of the surface with the areas of landslide developments demonstrate possible effect of deeply occurring deposits upon the landslide formation within the surface deposits. That may be caused by the features of hydrogeological structure and changes in lithological composition or rock conditions within the zones of irregular occurrence, resulting in their changed permeability or strength and favouring the formation of the areas of plastic flow within the slope subsoil.

That indicates the necessity of the comprehensive analysis of geological structure of the urban territories to elaborate landslide protection strategy. Determining the effect of the occurrence mode of surface deposits upon the erodible level does not allow defining all the factors influencing the mechanism and conditions of landslide occurrence.

Those conclusions may be proved by the immediate stability calculations for the slopes being the medium for landslide development. Results of the stability calculation for possible landslide bodies within a certain area are given as the example.

Loessial deposits occurring on the Neogene argillaceous deposits and weathering crust of the Archean-Proterozoic rock deposits are involved into geological structure of the slope.

Calculations are performed with the help of the *Geostab* licensed software. Possibility to substantiate

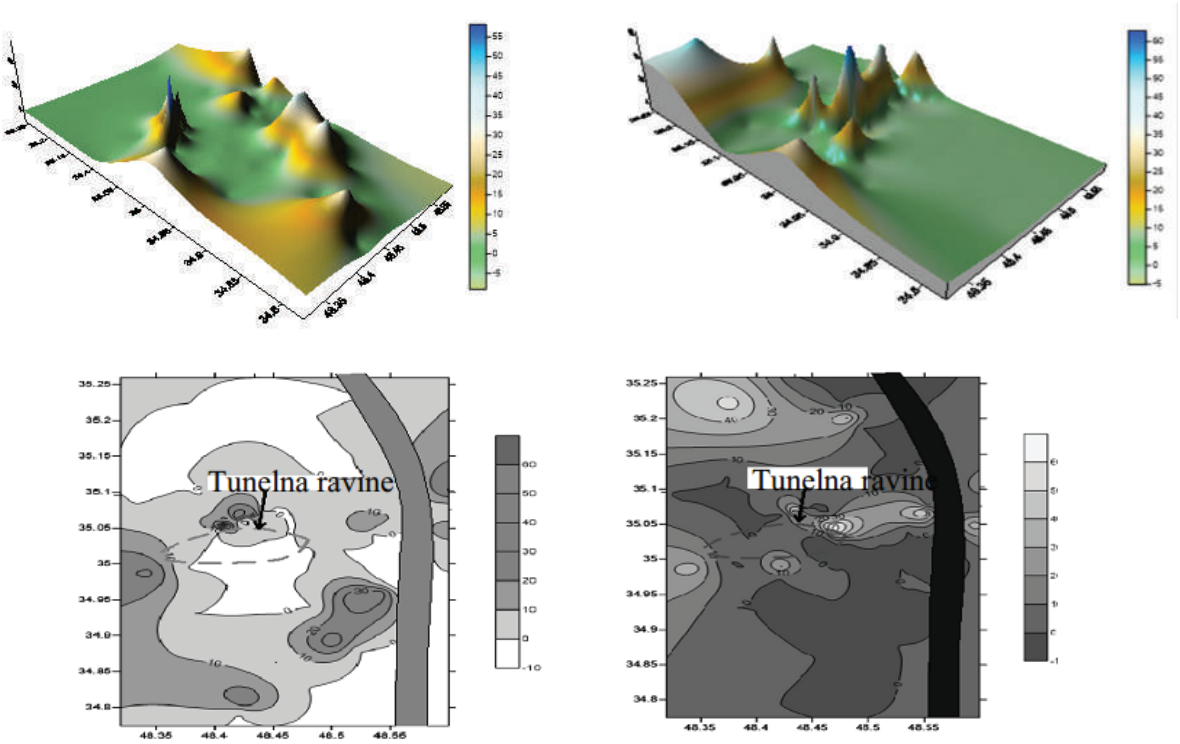

Fig. 5. Occurrence mode of the surfaces of certain levels of the Paleogene deposits – 3D model and isoline maps.

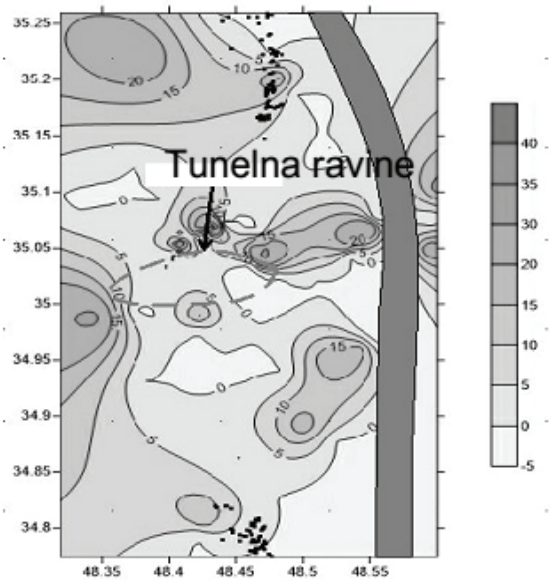

Fig. 6. Occurrence mode of Obukhivska and Mezhyhirska suites with the plotted landslide points.

the most probable landslide body location by solving optimization problem is the advantage of that software. While calculating, following variants of stability loss were considered:

loss of slope stability in its natural (initial) condition;

effect of the additional load due to buildings;

effect of the additional loads due to buildings and hydrostatic action of ground water;

effect of the additional loads due to buildings, hydrostatic flow action and consideration of the formation of the zone with changed slope stability;

Table 1 represents the data on physical and mechanical parameters having been used. According to the computational results, it has been determined that loss of slope stability is possible in terms of all the

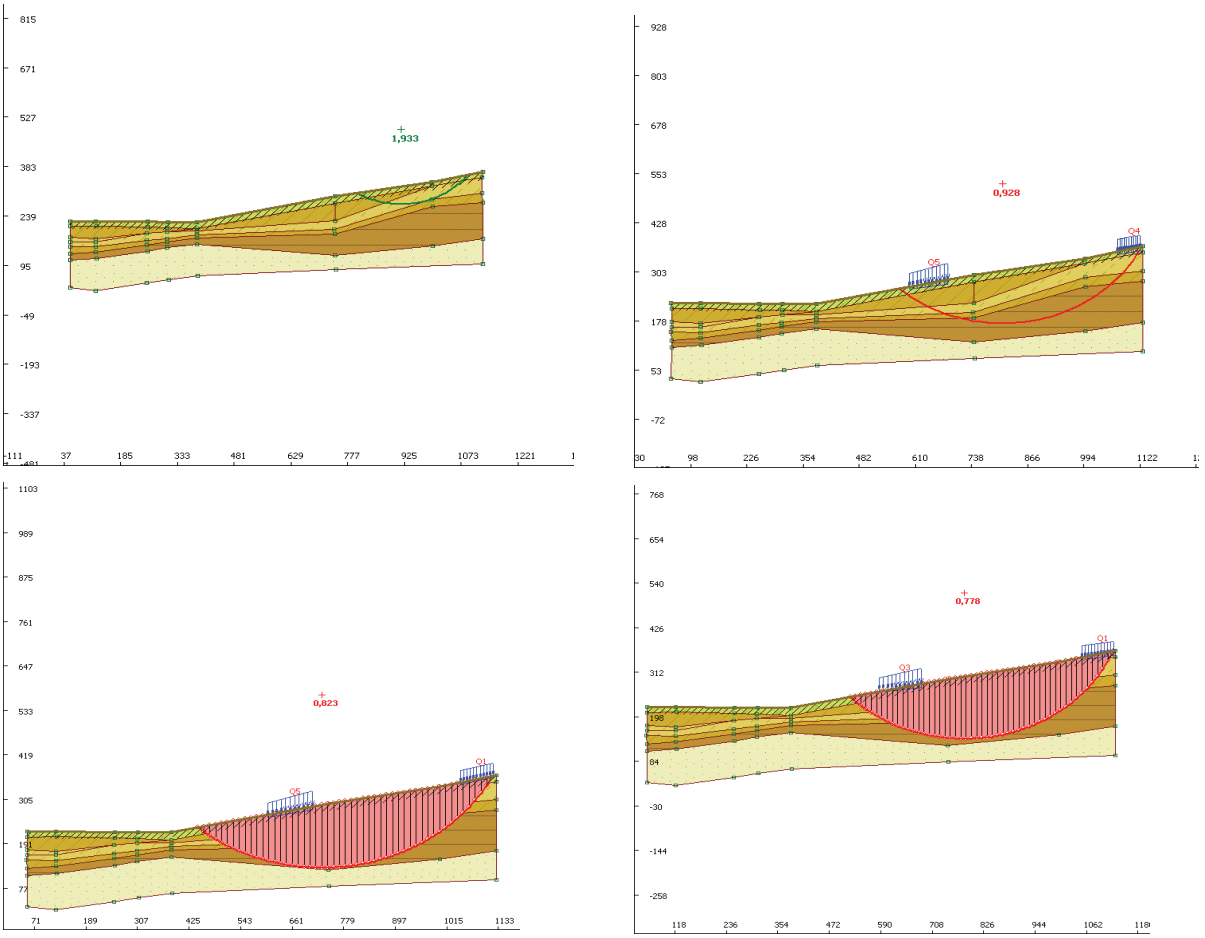

Fig. 7. The most probable landslides.

Legend:

- loessial deposits
- Clay deposits
- the most probable landslides
- coefficient of stability (slump).

variants taking into account additional loads. However, in terms of different variants, not only the coefficient value but also the volume of possible landslide body experiences certain changes.

Conclusions. According to the obtained modeling results, analysis of cartographic material, and calculations, following conclusions may be drawn:

loss of stability of the slope being stable in its natural condition, is possible in terms of technogenic effect as the results of mechanical and hydrodynamics actions;

in terms of different variants of changes in slope condition, not only surface loessial but also argillaceous deposits may be the medium for landslide developments;

occurrence mode of argillaceous soils is the factor effecting possible landslide developments;

while elaborating landslide protection systems, it is required to study mode of occurrence, composition, and properties of argillaceous soils.

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Table 1. Physical and mechanical properties of the soils in terms of calculation variant taking into account effect of the additional loads due to buildings

Number of layers	Soil type	Index		
		γ, kN/m^3	c, kPa	φ, degree
1	Loose	18	48	11
2	Loamy soil	19.01	48	11
3	Loamy soil	19.01	48	11
4	Loamy soil	15.38	16	17
5	Hard loamy sand	16.61	9	17
6	Medium-hard loamy soil	19.16	33	10
7	Plastic loamy sand	19.11	13	23
8	Hard loamy soil	19.68	31	6
9	Plastic loamy sand	20.08	26	26
10	Hard loamy soil	19.88	21	9
11	Hard clay	19.94	74	18
12	Hard clay	18.34	70	17
13	Fine sand	19.68	15	12

Key to Table 1:

γ – density of soil; c – cohesion; ϕ – friction angle

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Forecasting suffusion deformation in dispersive soils

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Abstract. Suffusion is a dangerous geological process accompanied by the formation of sinkholes, deformations of buildings and structures. Forecast of suffusion processes is a complex scientific problem since it is required to predict a complex process of the formation of new soil structure experiencing certain changes while interacting with the flow. During the period of 12.02.2018 – 13.04.2018, a sample of Dnipro loessial soil was filtered with the salt solution in Darcy device. The experiment was carried out at the SRI of Geology of Oles Honchar DNU; it is the continuation of the research dealing with experimental study of the dispersive soils as complex natural systems. To study suffusion process in loessial soils, analysis of microaggregate and granulometric composition of a sample of undisturbed structure of Dnipro loessial horizon taken in Tunelna ravine outcrop has been performed. The sample was studied in different states: natural and changed (due to long-term filtration) ones. Results of the use of innovative method to determine values of the function of particle distribution in terms of their mass and calculations of fractal dimension of the function basing upon the microaggregate analysis have made is possible to forecast values of porosity coefficient and volumetric deformation corresponding to the new quality standards of a complex system – dispersive soil in the state of complete microaggregate disturbance. Algorithm of the microaggregate composition analysis according to the methodology (Riashchenko, 2010) is in the fact that the sample experiences different methods of preparation – thus, evaluations of soil dispersivity are different. Basing upon the obtained results, values of microaggregate coefficient have been calculated, and data on the number of aggregates and initial particles have been taken. It has been determined that the basic size of the aggregates is 0.01-0.005 mm; there is a fewer share of the aggregates of 0.05-0.01 mm; and the fewest share of the aggregates is represented by fine fraction. That indicates the changes in microaggregate composition of soil due to the carrying out of fine fractions and the disturbance of larger aggregates. Calculations of the values of volumetric soil deformation due to long-term salt solution filtration emphasize the fact that within the zones of technogenic contamination, possible aggregate decay due to chemical effect will result in the formation of structure with denser particle packing, i.e. compaction. If loessial layers with the state changed due to salt solution filtration are subject to mechanical effect, drastic soil loosening and loss of soil stability may be observed.

Key words: suffusion, Dnipro loessial soil, fractal

Прогнозування деформації суфозії в дисперсних ґрунтах

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Анотація. Суфозія – небезпечний геологічний процес, що супроводжується формуванням провалів, деформаціями будівель і споруд. Прогноз суфозійних процесів представляє складну наукову проблему, так як потрібно спрогнозувати складний процес формування нової структури ґрунту що зазнає змін при взаємодії з потоком. На протязі двох місяців з 12.02.2018 р. по 13.04.2018 року зразок дніпровського лесового ґрунту був підвернутий фільтрації розчином соли у приладі Дарсі. Експеримент виконувався в НДІ геології ДНУ імені О.Гончара та є подовженням наукового напряму – експериментального дослідження дисперсних ґрунтів як складних природних систем. Для дослідження процесу суфозії в лесовому ґрунті був виконаний аналіз мікроагрегатного та гранулометричного складу зразка непорушеної структури дніпровського лесового горизонту, що був відібраний з відслонення у б. Тунельної. Зразок був досліджений у різних станах: у природньому та у зміненому в наслідок тривалої фільтрації. За результатами застосування нового методу встановлення значень функції розподілу часток за їх масою, розрахунків фрактальної розмірності функції на підставі мікроагрегатного аналізу доведена можливість прогнозу значень

коефіцієнту пористості та об'ємної деформації які відповідають новому якісному стану складної системи – дисперсному ґрунту у стані повного порушення мікроагрегатів. Алгоритм досліджень мікроагрегатного складу за методикою (Riashchenko, 2010) полягає в тому, що до зразка застосовують різні засоби підготовки, завдяки чому оцінки дисперсності ґрунту є різними. На підставі отриманих результатів, були розраховані значення коефіцієнту мікроагрегатності, отримані данні про кількість агрегатів та первинних часток. Встановлено, що агрегати мають розмір в основному 0,01-0,005 мм, агрегаті розміром 0,05-0,01 мм присутні у меншої кількості та кількість агрегатів тонких фракцій найменша. Це вказує на зміни мікроагрегатного складу ґрунту внаслідок виносу дрібних фракцій та на порушення агрегатів більших за розміром. Розрахунки значень об'ємної деформації ґрунту внаслідок тривалої фільтрації розчином солей вказують на те, що у зонах техногенного забруднення можливий розпад мікроагрегатів внаслідок хімічного впливу призведе до формування структури з більш плитною упаковкою часток, до стискання. Якщо лесові горизонти зі зміненим станом внаслідок фільтрації сольового розчину будуть підвергнути механічному впливу можливим є розпушення ґрунтів, можливим є різке розпушення та втрата стійкості ґрунту.

Ключові слова: суфозія, дніпровський лесовий ґрунт, фрактал

Introduction. Development of the experimental studies of the dispersive soil properties is the basis for successful solution of investment problems in the process of construction, especially within the zones characterized by complex geological processes. Suffusion is not often analyzed in engineering and geological studies. Nevertheless, it is known that suffusion phenomena within the areas of the available loessial soils is widely occurred and connected with subsidental, landslide, and erosive developments. Special attention is paid to the consideration of the processes in soil medium with the signs of fractal. Thus, studies of the processes of turbulence (Jafari et al., 2019), percolation (Ziani, 2019), peculiarities of soil behaviour within the shear zone (Lu et al., 2018) are carried out on the basis of the fractal theory elements. Wang et al. (2015) applied calculations of fractal size to define regularities of spatial changes in the properties of loessial soils to implement innovative recultivation methods. Liu et al., 2013, determined the connection between fractal volumetric size of natural soil particles and amount of organic substance and argillaceous particles. Suffusion methods are developed on the basis of classic techniques (Khuzhaerov, 1994), (Nikiforov, 2000). Research by Gudehus, & Touplikiotis, (2017) substantiates importance of the analysis of soils as natural fractals as for solving the problem of forecasting "building - soil" geotechnical system. Thus, review of literature sources indicates the necessity to study suffusion as a natural fractal. The paper represents the results of experimental research of the soils basing upon innovative methodology that helps predict suffusion deformation by applying fractal theory for the results of determination of microaggregate composition.

Materials and methods. Dispersive loessial soil masses of technogenically built-up territories are in constant dynamic transformation resulting in re-construction of the microstructure and changed physical, physical-mechanical, and hydrogeological properties of those soils. Increased level of ground water, transmission of constant and temporal static and dynamic loads, changes in thermal regime result in changing states of soil mass and soil properties both within the zone of complete water saturation and within the aeration zone.

Experimental studies of suffusion effect upon the loessial soils are carried out in terms of loessial soil sample of Dnipro horizon taken within the outcrop of Tunelna ravine erosive system. Geological section of the ravine slope under consideration down to 42.0 m from the land surface involves Quaternary deposits of loessial complex represented by layering of loamy soils and loamy sands, reddish-brown loamy soils, and underlying Neogene deposits – clays and sands. Ancient and modern landslides are recorded within the right slope of the ravine.

Soils samples under study were taken from the wall of modern landslide disruption and erosive-washed scarp slope. Physical and physical-mechanical characteristics were determined for Black Sea-Dofinivskyi eolian-deluvial loamy soils (vd PIII pc+df), Bug eolian-deluvial loamy sands (vd P III bg), and Dnipro eolian-deluvial loamy sands (vd P II dn). The soil layers are irregular in their thickness and strike. Within the upper share of the slope, loessial thickness is from 38.8 down to 27.7 m; within the medium share, the thickness is down to 10.6 m; and within the lower share, the thickness is down to 0.0 m. In terms of hydrogeology, one Quaternary water-bearing level located in the loessial deposits of the right ravine slope (vd-e PIII-II pl + kd, vd PII dn, e PII zv) is recorded within the right Tunelna ravine slope down to the prospected depth.

Results and discussion. The research involves modeling of the suffusion processes due to long-term filtration involving 10% solution of NaCl salt (Fig. 1).

Data concerning changes in the filtration coefficient have been obtained, and calculations of salt content in the solution after the process stabilization have been performed. During the period of 12.02.2018 - 13.04.2018, sample of Dnipro loessial soil was being

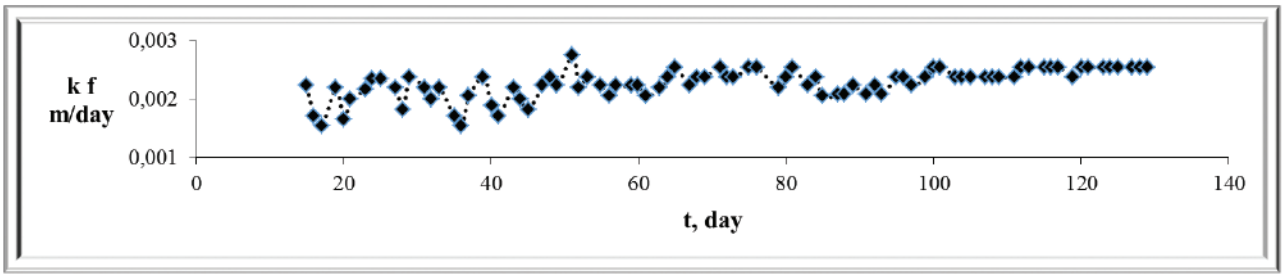

Fig.1. Dynamics of changes in the filtration coefficient according to the experimental results in terms of stable regime.

filtered in Darcy device. Layout and methodology of the research corresponded to the previously completed studies. Liquid volume was measured along with the determination of the filtrate composition in final phase of the experiment when stable regime was obtained (Fig.1). Calculations of the compositions of different. Thus, sample one was subject to mechanical shaking during 2 hours, sample two was prepared with the addition of ammonia solution and boiled during one hour, and sample three was boiled during one hour with the addition of sodium pyrophosphate solution. After that, suspended matter was sampled from

Table 1. Results of chemical analysis of soil samples and filtrates.

Number	pH	HCO^-_3		Mg^{2+}		Ca^{2+}		Cl^-		SO_4^{2-}		$Na^+ + K^+$		∑ of ions, mg/ 100 g	Dry residue, mg/100 g
		mg-eq	mg/ 100 g	mg-eq	mg/ 100 g	mg-eq	mg/ 100 g	mg-eq	mg/ 100 g	mg-eq	mg/ 100 g	mg-eq	mg/ 100 g		
1	7.40	0.40	0.024	0.6	0.007	1.90	0.038	1.62	0.056	0.58	0.028	0.100	0.002	0.143	0.147
2	7.42	0.63	0.038	6.06	0.074	12.62	0.252	16.27	0.577	18.38	0.882	16.60	0.382	2.186	2.192
3	7.75	0.77	0.047	5.97	0.073	28.98	0.580	29.42	1.043	20.24	0.972	15.48	0.356	3.048	3.050
4	7.84	0.51	0.031	1.67	0.020	7.34	0.147	15.58	0.552	3.29	0.158	10.37	0.239	1.132	1.134

Table 2. Calculation of hypothetic salts.

Number	$Ca(HCO_3)_2$		$CaSO_4$		$MgSO_4$		Na_2SO_4		NaCl		$CaCl_2$		$MgCl_2$	
	mg-eq	%	mg-eq	%	mg-eq	%	mg-eq	%	mg-eq	%	mg-eq	%	mg-eq	%
1	0.80	15.38	1.16	22.31	-	-	-	-	0.2	3.85	1.84	35.38	1.2	23.08
2	1.26	1.79	23.98	33.98	12.12	17.18	0.66	0.94	32.54	46.11	-	-	-	-
3	1.54	1.53	40.48	40.13	-	-	-	-	30.96	30.70	15.94	15.80	11.94	11.84
4	1.02	2.63	6.58	16.98	-	-	-	-	20.74	53.51	7.08	18.27	3.34	8.61

hypothetic salts are represented below (Tables 1, 2).

Objective of the study was to determine changes in granulometric composition of the loessial soil sample due to long-term salt solution filtration. That process models the effect upon granulometric composition of chemical and mechanical suffusion. To study suffusion process within the loessial soil, microaggregate and granulometric composition of the regular-structure sample of Dnipro loessial horizon sampled within Tonelna ravine outcrop has been analyzed.

Algorithm of microaggregate study according to the methodology (Riashchenko, 2010) is as follows: the sample experiences different methods of preparation so that evaluations of soil dispersion would be the depths of 25, 10, and 7 cm (in an hour interval) being determined by the standard and depending upon the temperature. Mass value of the average sample is used to define quantitative fraction content according to formula:

$$X=A*1000*(100-K)/(g_0*V_n) \quad (1)$$

where, A - is mass of soil fraction within the sample of the known volume brought to the constant mass value, g;

g_0 - is mass of absolute dry soil sample, initial value, g;

V_n - is pipette capacity, cm^3;

K - is total content of soil fraction of the size more

than 1 mm, %.

Results of the study of microaggregate composition of the sample being subject to long-term salt solution filtration have made it possible to determine certain changes in microaggregate soil composition. Percentage content of the particles according to the study results is represented below (Table 3).

Table 3. Percentage content of fraction particles.

Method of sample preparation	Percentage content of particles of the indicated fraction, mm					
	0.1-0.05	0.05-0.01	0.01-0.005	0.005-0.002	0.002-0.001	less than 0.001
Aggregate	43.353	21.763	31.433	0.000	2.713	3.274
Semi-disperse	33.580	64.053	0.000	2.037	3.030	0.095
Disperse	77.944	15.169	0.000	4.393	9.431	2.047

Basing upon the obtained results, coefficient values of microaggregation have been calculated; data on the amount of aggregates and initial particles have been obtained. It has been determined that the aggregates size is mostly 0.01-0.005 mm; aggregates of 0.05-0.01 mm are found less often; and fine-fraction aggregates demonstrate the least amount. That indicates certain changes in microaggregate soil composition due to the carrying out of fine fractions and the disturbances of larger aggregates. Content of the initial particles and content of the particles in microaggregates of the corresponding fractions have been calculated (Table 4).

Table 4. Percentage content of the initial particles

Parameter	M1	M1-a	M2	M2-a	M3	M3-a	M4	M4-a	M5	M5-a	M6	M6-a
Percentage content of particles, %	43,353	34,591	15,169	-	-	-	-	4,393	2,713	6,717	2,047	-
Fraction size, mm	0,1-0,05		0,05-0,01		0,01-0,005		0,005-0,002		0,002-0,001		Less 0,001	

Note for Table 4:
M1 – content of the initial particles;
M1-a – content of the particles in aggregates.

Table 5. Results of the calculation of forecast values of the porosity coefficient

Method of sample preparation for the analysis	Value of fractal size of the function of particles distribution in terms of their mass D	Claculation coefficient value	Forecast value of the porosity coefficient k'
Aggregate	0.189	0.738	0.961
Disperse	0.071	0.892	0.668
Semi-disperse	0.212	0.711	1.019

No availability of the initial particles of fine argillaceous composition and general decrease in the amount of fine particles comparing to the natural state of sample preparation (Fig 2).

According to the methodology (Mokrytska, Tushev et al., 2018), values of fractal size of the functions of particle distribution in terms of their mass have been calculated (Fig.3). Values of the determination coefficient of linear trend equations indicate considerable importance of the obtained equations. Value of angle coefficient shows the effect of the preparation method upon the value of fractal size of the function of particles distribution in terms of their mass.

Next stage involves calculation of the porosity coefficient value of soil in terms of complete decay of samples microaggregates having experienced mechanical or chemical action of different degree (Table 5). Those values are the forecast ones indicating porosity value of the soil medium having experienced

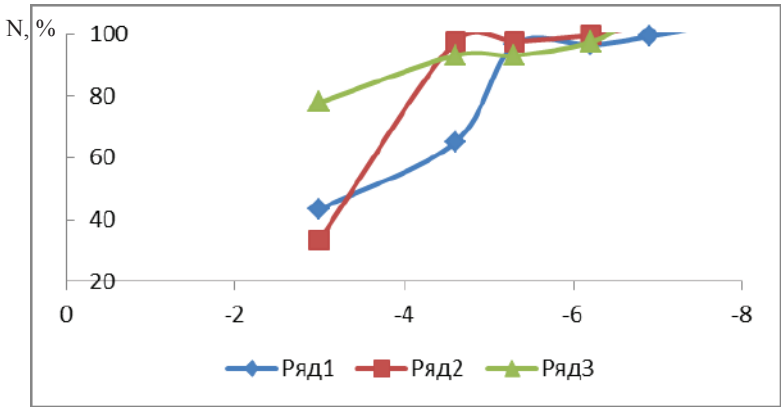

Fig. 2. Cumulative curves of granulometric composition of the sample of Dnipro loessial horizon having been subject to long-term salt solution filtration

Notes for Fig. 2:

N, % - total number of particles;

ln R – logarithm of particle size;

Row 1 – aggregate method of sample preparation (mechanical shaking during 2 hours);

Row 2 – semi-disperse method of sample preparation (with the addition of ammonia solution);

Row 3 – disperse method of sample preparation (with the addition of sodium pyrophosphate solution).

Table 6. Forecast values of the deformation of the sample of Dnipro loessial horizon.

Results of calculation of forecast deformation of the sample of Dnipro loessial horizon vdP II dn				
Method of sample preparation	**Value of fractal size of the function of particles distribution in terms of their mass**	**Porosity coefficient of a natural-state sample**	**Porosity coefficient of a changed-state sample**	**Volumetric sample deformation**
Aggregate preparation	2.669	0.706	0.74	-0.034
Preparation with magnetic shaker	2.706	0.718	0.741	-0.023
Preparation as long-term water solution filtration	2.605	0.711	0.737	-0.027

Table 7. Forecast deformation values due to salt solution filtration

Method of soil preparation	**Porosity coefficient of a natural-state sample**	**Porosity coefficient of a changed-state sample**	**Volumetric sample deformation**
Aggregate preparation	0.711	0.96	-0.249
Semi-disperse preparation		1.019	-0.308
Disperse preparation		0.668	0.04

long-term salt solution filtration and mechanical or chemical effect resulting in complete decay of all the microaggregates.

Comparison of the obtained values with the porosity coefficient values of natural-state soil (Table 5) and changed soil (Table 7) demonstrates the expected consequences of the effect of suffusion process upon the porosity of Dnipro loessial horizon sample.

While analyzing the data, it should be noted that disturbance of microaggregates results in the formation of looser structure; in this context, filtration is less important factor than the action of magnetic field or mechanical shaking.

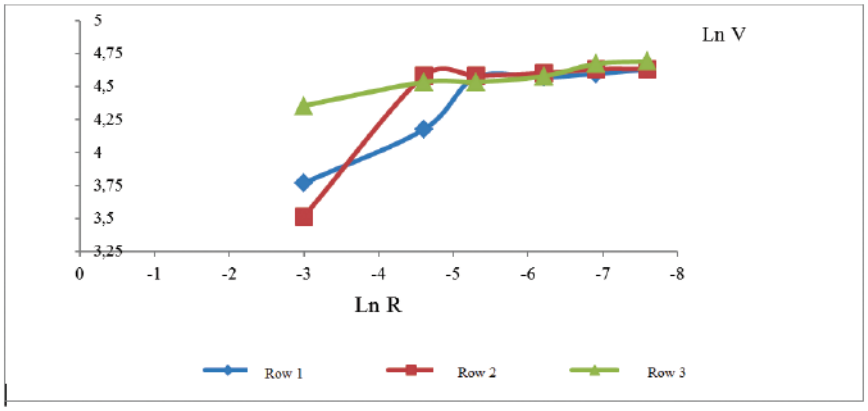

Fig.3. Graphs of the dependence of logarithm of particle distribution function in terms of the mass upon the logarithm of particle sizes.

Note for Fig. 3:

Ln V, % - total volume of particles;
Ln R – logarithm of particle size;
Row 1 – aggregate method of sample preparation;
Row 2 – disperse method of sample preparation;
Row 3 – semi-disperse method of sample preparation.

According to the results of previous studies due to filtration with water solution, increased coefficient of soil porosity should be expected. Calculations of the values of soil volumetric deformation due to long-term filtration with salt solution show the fact that possible microaggregates decay within the zones of technogenic contamination due to chemical effect will result in the formation of structure with denser particles packing, i.e. compaction.

If loessial horizons with the changed state due to salt solution filtration are subject to mechanical effect, there is possible soil loosening (even, drastic loosening) and loss of soil stability.

Thus, comparison of the results shows considerable changes in the soil state due to suffusion within the zones of technogenic contamination. Certain regularities of changes in soil porosity in the state of complete degradation in terms of complete decay of microaggregates due to mechanical suffusion or processes of solution and carrying out of particles during salt solution filtration have been defined. It has been demonstrated that density deformation is possible only in the context of disperse preparation in terms of maximum decay of microaggregates.

Conclusions and their discussion. The paper represents the results of long-term experiment on determining regularities of changes in loessial soil state within the zones of technogenic action.

Effect of chemical composition of the solution upon the regularities of changes in granulometric and microaggregate soil composition has been confirmed.

It has been proved that suffusion may result in loss of soil strength and compaction.

For the first time, forecast values of the porosity coefficient of loessial Dnipro horizon have been obtained; the values will correspond to new soil state.

For the first time, the experimental results have made it possible to prove the possibility to obtain forecast values of the properties of the medium experiencing certain changes due to suffusion.

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Assessment of environmental risks from atmospheric air pollution in industrially developed regions of Ukraine

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Abstract. Currently, atmospheric pollution is one of the main causes of premature mortality in the world. The problem is especially relevant for economically underdeveloped countries, in particular Ukraine, the economy of which has been developing for a long time in an extensive way. The complicated socio-ecological situation in the territory of the country is due, first of all, to insufficient financing of the medical industry and environmental protection, outdated technologies in industries, etc. The purpose of the study is to assess the environmental risks of atmospheric air pollution in industrialized regions of Ukraine. Kharkiv and Dnipro regions, which are part of the Donetsk-Prydnistrovsky economic macro-district, a powerful center of metallurgy and machine-building of the national level, were selected for the study. As part of the study, the ambient air condition was assessed from the point of view of sanitary-hygienic norms in compliance with state environmental standards as well as the risks of carcinogenic and non-carcinogenic effects from atmospheric pollution.Regional monitoring data on average annual concentrations of common pollutants and heavy metals in the atmospheric air of the cities of Kharkiv and Dnipro regions were used in calculations, averaged over the period from 2014 to 2016. The results of calculations have shown that the total non-carcinogenic risk from atmospheric air pollution in all studied cities exceeds the permissible level: Dnipro – 19.8 HQ; Kamianske– 23.3 HQ; Kryviy Rig – 19.3 HQ; Kharkiv – 11.9 HQ. The pollutants: $PM_{2.5}$, copper, formaldehyde, nitrogen dioxide, manganese and phenol mostly contribute to the greatest non-carcinogenic risk. The dominance of these chemicals and elements in the structure of pollution in the studied cities leads to high probability of development of harmful effects in the respiratory organs – 11.1 to 22.3 HQ; cardiovascular system – 2.9 to 12.3 HQ; immune system – 1.7 to 4.7 HQ; eyes – 0.8 to 4 HQ; central nervous system – 1,4 to 4,6 HQ. The risk of carcinogenic effects is calculated for substances with proven carcinogenic effects: formaldehyde, nickel, cadmium, lead and chromium. The obtained carcinogenic risk from atmospheric air pollution within the studied cities falls into two categories: conventionally acceptable level of risk and acceptable level of risk. The greatest carcinogenic danger is from pollution of atmospheric air by chromium. Contribution of chromium to total carcinogenic risk ranges from 53.6 to 90.6%. Taking into account the obtained results, it is expedient to include the assessment of the risks to the population's health in the system of monitoring and control of the environment in Ukraine.

Keywords: environmental safety, population health, heavy metals, atmospheric air, carcinogenic risk, non-carcinogenic risk

Оцінка екологічних ризиків від забруднення атмосферного повітря у промислово розвинених регіонах України

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Анотація. Сьогодні забруднення атмосфери належить до головних причин передчасної смертності у світі. Особливо актуальною проблема є для економічно слаборозвинених країн, зокрема України, економіка якої тривалий час розвивалась екстенсивним шляхом. Складна соціально-екологічна ситуація на території держави обумовлена, насамперед, недостатнім фінансуванням медичної галузі і охорони довкілля, наявністю застарілих технологій на виробництвах тощо. Мета дослідження – оцінка екологічних ризиків від забруднення атмосферного повітря у промислово розвинених регіонах України. Для дослідження обрано Харківську і Дніпропетровську області України, які входять до складу Донецько-Придніпровського економічного макрорайону – потужного центра металургії і машинобудування національного рівня. У рамках дослідження проведено санітарно-гігієнічну оцінку стану атмосферного повітря на відповідність державним екологічним нормативам, оцінку ризиків розвитку канцерогенних і неканцерогенних ефектів від забруднення атмосферного повітря. При виконанні розрахунків

використані дані регіонального моніторингу щодо середньорічних концентрацій загальнопоширених забруднюючих речовин і важких металів в атмосферному повітрі міст Харківської і Дніпропетровської областей, усереднені за період із 2014 по 2016 рік. Результати розрахунків показали, що сумарний неканцерогенний ризик від забруднення атмосферного повітря в усіх досліджуваних містах перевищує допустимий рівень: м. Дніпро – 19,8 HQ; м. Кам'янське – 23,3 HQ; м. Кривий Ріг – 19,3 HQ; м. Харків – 11,9 HQ. Найбільший внесок у сумарний неканцерогенний ризик вносять такі полютанти: пил, мідь, формальдегід, діоксид азоту, марганець і фенол. Домінування зазначених хімічних речовин та елементів у структурі забруднення обумовлює для населення досліджуваних міст високу імовірність розвитку шкідливих ефектів в органах дихання – від 11,1 до 22,3 HQ; серцево-судинній системі – від 2,9 до 12,3 HQ; імунній системі – від 1,7 до 4,7 HQ; очах – від 0,8 до 4 HQ; ЦНС – від 1,4 до 4,6 HQ. Ризик розвитку канцерогенних ефектів розраховано для речовин із доведеною канцерогенною дією: формальдегід, нікель, кадмій, свинець та хром. Отримані значення канцерогенного ризику від забруднення атмосферного повітря у межах досліджуваних міст належать до двох категорій: умовно прийнятний рівень ризику і прийнятний рівень ризику. Найбільшу канцерогенну небезпеку представляє забруднення атмосферного повітря хромом. Внесок хрому у значення сумарного канцерогенного ризику складає від 53,6 до 90,6 %. Враховуючи отримані результати, доцільним є включення оцінки ризиків для здоров'я населення до системи моніторингу і контролю за станом довкілля в Україні.

Ключові слова: екологічна безпека, здоров'я населення, важкі метали, атмосферне повітря, канцерогенний ризик, неканцерогенний ризик

Introduction. Intensification of processes of technogenesis in the 20th century has caused contamination of the components of the environment, which in some territories reached critical levels for people's life and health . In particular, in London in 1952 atmospheric air pollution combined with temperature inversion led to the formation of a powerful smog, which, according to various estimates, killed about 12,000 people (Bell, Davis, & Fletcher, 2004). A similar case with fewer victims occurred earlier in Belgium in 1930. At that time, smog with an increased content of sulfur dioxide caused premature deaths of more than 60 people.

Awareness of the catastrophic consequences of the disruption of the ecosystem balance prompted national governments to legislatively approve acceptable levels of environmental pollution. However, the establishment of environmental restrictions have far from entirely succeeded in getting rid of the effects of negative technogenesis on human life and health. According to Landrigan et al., 2017, due to diseases caused by environmental pollution 9 million people died prematurely in the world in 2015. This includes 6.5 million people who died from the pollution of atmospheric air, clearly the greatest source of danger**.**

Environmental problems for countries with low and average income levels,where the death rate due to environmental pollution is 92% of the global indicator, are particularly relevant today (Landrigan et al., 2017). The complicated environmental situation is usually caused by the industrialized economy, a high proportion of energy-intensive and material-intensive industries, outdated technologies, insufficient expenditures on environmental protection needs and on medicine, and so on. Taking the above into account, there is a need for research in the field of environmental safety assessment of such regions with regard to human life.

Analysis of recent research and publications. Analysis of present-day research in the field of environmental safety indicates the priority of the problem of air pollution in most regions of the world. In the United States alone, changes in the concentration of $PM_{2.5}$ in the surface layer of the atmosphere annually lead to 200.000 premature deaths, in O^3–to 10,000 premature deaths (Caiazzo, AshokIan, Waitz, Yim, & Barrett, 2013). In China, between 2004 and 2012, the number of premature deaths from atmospheric $PM_{2.5}$ increased from 0.8 to 1.2 million per year (Liu et al., 2017). The economic loss from the negative impact of atmospheric air pollution on health in Europe and the United States is estimated at 300 and 145 billion euros, respectively (Im at al., 2018).

Particular attention in modern studies is devoted to the influence of meteorological conditions on the quality of atmospheric air. The authors (Revich et al., 2015) determined the dependence of mortality increases of 0.47 and 0.41% on an increase in daily average concentrations of PM_{10} and O^3 by 10 $\mu g/m^3$, respectively, during the period of abnormal heat in Moscow. Research results (Wang, Chen, & Liu, 2015), conducted in China indicated a positive correlation between the reduction of the Arctic sea ice area and the increase in the number of foggy days in the country. Taking into account further reduction of the ice cover due to global warming [Maksymenko, Medvedeva, & Cherkashyna, 2019], a tendency to increase in the number of days with favourable conditions for the formation of smogs becomes a significant factor in increasing the level of environmental hazard in the region.

A significant number of Ukrainian scientists are devoting their research to the problems of regionalization and spatio-temporal structuring of environmental hazards, and selection of criteria for the establishment of danger levels, etc. In particular,

in the work (Yatsenko & Ivaniuta, 2013) it is proposed to add the indicator of density of the common pollutants' emissions per unit area or per capita to the normative indicators of the air quality assessment. A similar approach is used by the authors (Ivaniuta & Kachynskyi, 2013) when ranking the administrative regions of Ukraine on the basis of pollutant emissions per capita. It is carried out in relation to the administrative area with the highest value of the indicator adopted for 1. The assessment methodology of the condition and development of the regions by the ITSEEDI index is developing, allowing one to consider the connection between the subsystems of the environment based on the integrated approach(Nekos & Soloshych, 2014).

An overview of recent studies in the field of environmental safety of the regions of Ukraine shows that the problem of excesses over sanitary and hygiene standards receives the bulk of attention. This approach does not allow to take into account the physiology of the cohort, the quantification of the probability of diseases and mortality among the population, or attempt to determine the critical organs and systems of the human body, subject to the exposure to certain pollutants. Considering the above, it is expedient to assess environmental safety, including safety of atmospheric air, as a criterion for the health risks of the population.

The purpose of the work is to assess the environmental risks of atmospheric air pollution in industrialized regions of Ukraine.

Materials and methods of research. During the study, the materials of "Regional reports on the state of the environment" in Kharkiv and Dniproregions of Ukraine for the period from 2014 to 2016 were used, namely, the data of average annual content of pollutants in the atmospheric air of the following cities: Kharkiv, Dnipro, Kryvy Rih and Kamianske. The materials used are official public open access data. The monitoring of atmospheric air is carried out on a regular basis by the regional subdivisions of the Ministry of Ecology and Natural Resources of Ukraine.

Assessment of the dangers of atmospheric air pollution for the health of the population was carried out according to the risk criterion for the development of carcinogenic and non-carcinogenic effects according to the methodology (Rukovodstvo po ocenke riska dlja zdorov'ja naselenija pri vozdejstvii himicheskih veshhestv, zagrjaznjajushhih okruzhajushhuju sredu, 2004). Carcinogenic risk is calculated according to formulae 1.1 and 1.2. In assessing carcinogenic risk, standard values of exposure were used: human weight – 70 kg, period of exposure averaging and duration of exposure – 70 years, the volume of atmospheric air entering the human body – 20 m^3/day.

$$CR = LADD \cdot SF, \quad (1.1)$$

where

CR – individual carcinogenic risk;

LADD – daily average intake during life, mg / (kg · day);

SF – tilt factor mg/(kg·days)$^{-1}$

$$LADD = \frac{C \cdot CR \cdot ED \cdot EI}{BW \cdot AT \cdot 36}, \quad (1.2)$$

where

C – concentration of the substance in the contaminated environment, mg/m^3;

CR – rate of admission to an organism, m^3/day;

ED – duration of exposure, years;

EF – frequency of exposure, days/year;

BW – body weight, kg;

AT – period of averaging of the exposure;

365 – number of days in a year.

The risk of development of non-carcinogenic effects in the population from atmospheric air pollution is calculated according to the formula 1.3 (Rukovodstvo po ocenke riz dlja zdorov'ja naselenija pri vozdejstvii himicheskih veshhestv, zagrjaznjayushhih okruzhajushhuju sredu, 2004).

$$HQ = AC / RfC, \quad (1.3)$$

where

HQ –hazard quotient;

AC – average concentration, mg/m^3;

RfC – reference concentration, mg/m^3.

Research results. Kharkiv and Dnipropetrovs'k regions of Ukraine, which are part of the Donetsk-Prydniprovsk economic macro-district - the center of fuel and energy, metallurgical and machine-building industries of state level, have been selected for the research on the assessment of the airborne hazard. The industrial cluster of the region was formed in the "Soviet times" under the conditions of an extensive economy. This kind of economic activity due to neglect of environmental principles and laws has led to significant pollution of local ecosystems and other types of environmental degradation. According to data (Shmandii et al., 2013), Dnipropetrovsk region belongs to the regions with an extremely high level of environmental hazards, and Kharkiv region – to regions with a high level of environmental hazards.

It should be noted that as of 2018, about 2.68

and 3.21 million people live permanently within the limits of Kharkiv and Dnipropetrovsk regions, respectively. The complicated ecological situation in a densely populated territory can lead to significant socio-economic losses due to the increased risk of morbidity and mortality. Thus, the state of the natural environmental components of the region, including the quality of the air, requires special control by the authorized bodies of state power.

Today, the tasks of monitoring the quality of atmospheric air within the settlements of the studied territory are implemented by the Regional Hydrometeorological Centers. Monitoring is carried out daily at specially equipped stations in the largest cities of Kharkiv and Dnipropetrovsk regions: Kharkiv, Dnipro, Kryvy Rih and Kamianske. The monitoring programme includes indicators of common pollutants and substances that are monitored at regional and local levels.

Sanitary hygienic assessment. Indicators of pollutants' content for the period from 2014 to 2016 were averaged for the preliminary assessment of atmospheric air hazards within the settlements of Kharkiv and Dnipropetrovsk regions. The obtained averaging values were compared with the maximum permissible concentration – MPC accepted in Ukraine (Fig. 1).

The results of the sanitary-hygienic assessment of atmospheric air show that the average annual concentration of formaldehyde is exceeded – from 3.1 to 4 times; $PM_{2.5}$– from 2.4 to 3.8 times; nitrogen dioxide – from 1.4 to 2.2 times in all the studied towns of Dnipropetrovsk region. Excess of phenol and ammonia annual average MPC is characteristic only for Kamianske town– in 2.3 and 1.2 times, respectively. The average annual content of carbon monoxide in it is within the limit-acceptable value – 1 MPC. Unlike the situation in Dnipropetrovsk region, excessive average annual MAC of pollutants in the atmospheric air of the city of Kharkiv has not been recorded.

Assessment of non-carcinogenic risk. A significant excess of the MAC in chemicals and elements indicates a dangerous level of air pollution within the studied cities, which necessitates a detailed assessment of the health risks of the population. Consequently, the risk of development of non-carcinogenic HQ effects is calculated on the condition of inhalation supply of pollutants (Fig. 2).

The results of the study show that the level of total non-carcinogenic risk at simultaneous exposure of pollutants in all cities exceeds the limit acceptable value – 1. In particular,this risk for the population of the city of Dnipro is 19.8 HQ; Kamianske– 23.3 HQ; Kryviy Rih – 19.3 HQ; Kharkiv – 11.9 HQ. It should be noted that the likelihood of development of harmful effects increases in proportion to the increase in the risk value. Thus, the most dangerous level of atmospheric air pollution among the studied cities is characteristic for the town of Kamianske, the least dangerous – for the city of Kharkiv.

Characterizing the non-carcinogenic risk of certain chemicals and elements, we note that the greatest danger to the health of the population is the pollution of atmospheric air with $PM_{2.5}$– the permissible level of risk in all cities was exceeded

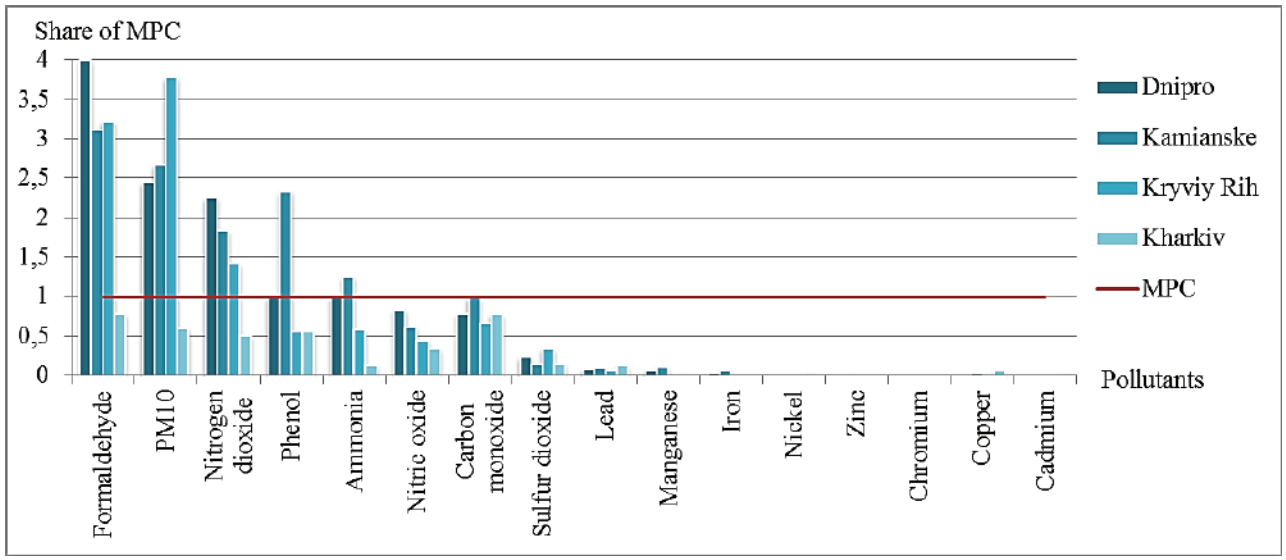

Fig. 1. Assessment of atmospheric air hazard within the settlements of Kharkiv and Dnipropetrovsk regions by criterion of MAC (2014-2016).

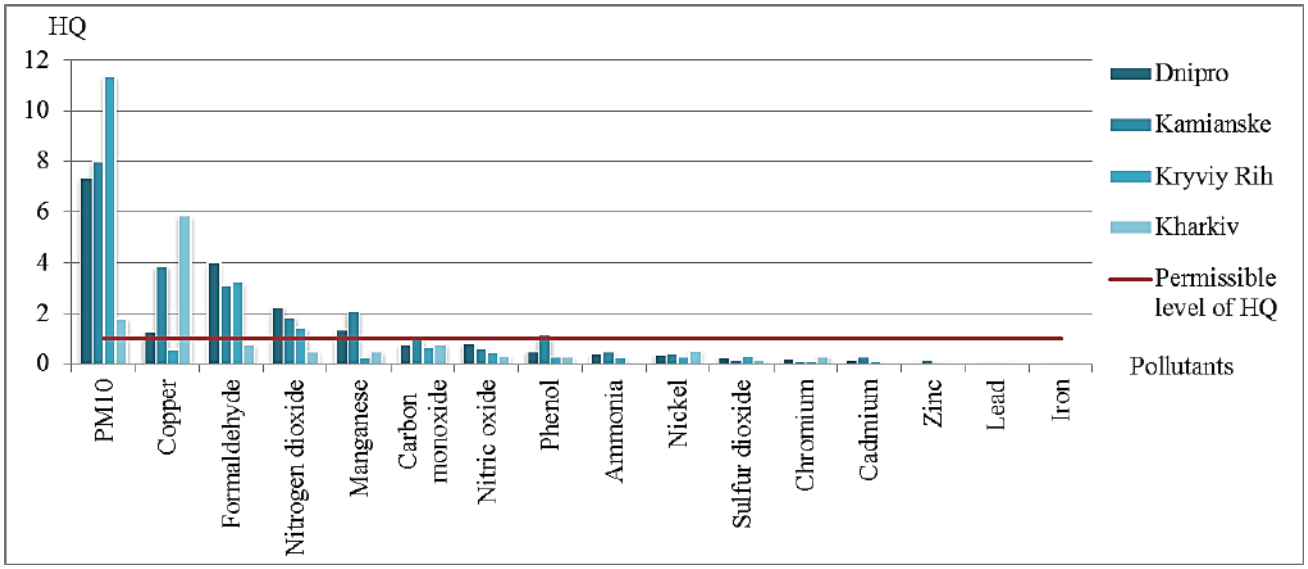

Fig.2. Assessment of non-carcinogenic risk from atmospheric air pollution within the settlements of Kharkiv and Dnipropetrovsk oblasts (2014 - 2016)

from 1.8 to 11.3 times. In the towns of Dnipropetrovsk region the predominant pollutants are formaldehyde and nitrogen dioxide. The range of non-carcinogenic risk values for formaldehyde is from 3.1 to 4 HQ; by nitrogen dioxide – from 1.42 to 2.2 HQ.

Significant local differences can be traced in pollution of atmospheric air with copper and manganese. Thus, the highest value of non-carcinogenic risk for copper is characteristic for the population of Kharkiv city – 5.8 HQ. The non-carcinogenic risk indicator for the population of Kryviy Rih for copper and manganese, in contrast to other towns in Dnipropetrovsk region, corresponds to the permissible level.

Thus, in the atmospheric air of the studied cities there is an observed excess of the reference concentrations of the following pollutants: $PM_{2.5}$, copper, formaldehyde, nitrogen dioxide, manganese and phenol. These pollutants are capable of causing various harmful effects in the human body. In particular, the influence of $PM_{2.5}$ and other solid particles is associated with cardiovascular and cerebrovascular diseases (Anderson, Thundiyil, & Stolbach, 2012). Excess of copper causes liver disorders and neurodegenerative changes in the body (Uriu-Adams & Keen, 2005), endemic anemia, growth retardation, loss of light sensitivity, etc. (Nekos & Kholin, 2015). Formaldehyde has a proven carcinogenic effect, may cause eye irritation and respiratory tract infections (Rovira, Roig, Nadal, Schuhmacher, & Domingo, 2016). Also, formaldehyde affects the nervous system, respiratory tract, liver and kidneys; can lead to anomalies of fetal development due to teratogenic properties (Malyutina, & Taranenko, 2014). Pollution of atmospheric air with nitrogen dioxide is dangerous because of the risk of respiratory infections in the interaction of pollutants with the immune system (Chen, Kuschner, Gokhale, & Shofer, 2007). The toxic effects of manganese are connected with neurodegenerative disorders, manganese-induced parkinsonism or manganism (Avila, Robson, & Aschner, 2013). Chronic phenol poisoning can cause damage to the central nervous system, kidneys, liver, respiratory and cardiovascular systems (Shipicyna, Vasilenko, Gadaborsheva, & Chichirov, 2017). Given the significant differentiation of the effects of chemicals and elements, it is advisable to identify the critical organs and systems of the human body, subject to the exposure of all studied pollutants (Fig. 3).

The results of the study show that the highest risk of developing non-carcinogenic effects from atmospheric air pollution is characteristic of the following organs and systems: respiratory organs – from 11.1 to 22.3 HQ; cardiovascular system – from 2.9 to 12.3 HQ; immune system - from 1.7 to 4.7 HQ; eyes – from 0.8 to 4 HQ; central nervous system – from 1.4 to 4.6 HQ. The range of values for the risk of normal body development disorder is from 2.7 to 12 HQ. For blood, the greatest risk is related to the formation of methemoglobin – from 0.83 to 3.08 HQ. It should be noted that the formation of methemoglobin leads to the loss of iron ability to bind and transport oxygen in the body (Fatkulin, Gil'manov, & Kostjukov, 2014). When the content of methemoglobin is more than 1% in the blood, a person develops methemoglobinemia – a state that is accompanied by headache, weakness, tachycardia and other negative effects.

Assessment of carcinogenic risk. Among the studied pollutants are chemicals and elements that have a carcinogenic effect, that is, the ability to cause malignant neoplasms. Carcinogens, in particular, include: formaldehyde, nickel, cadmium, lead and

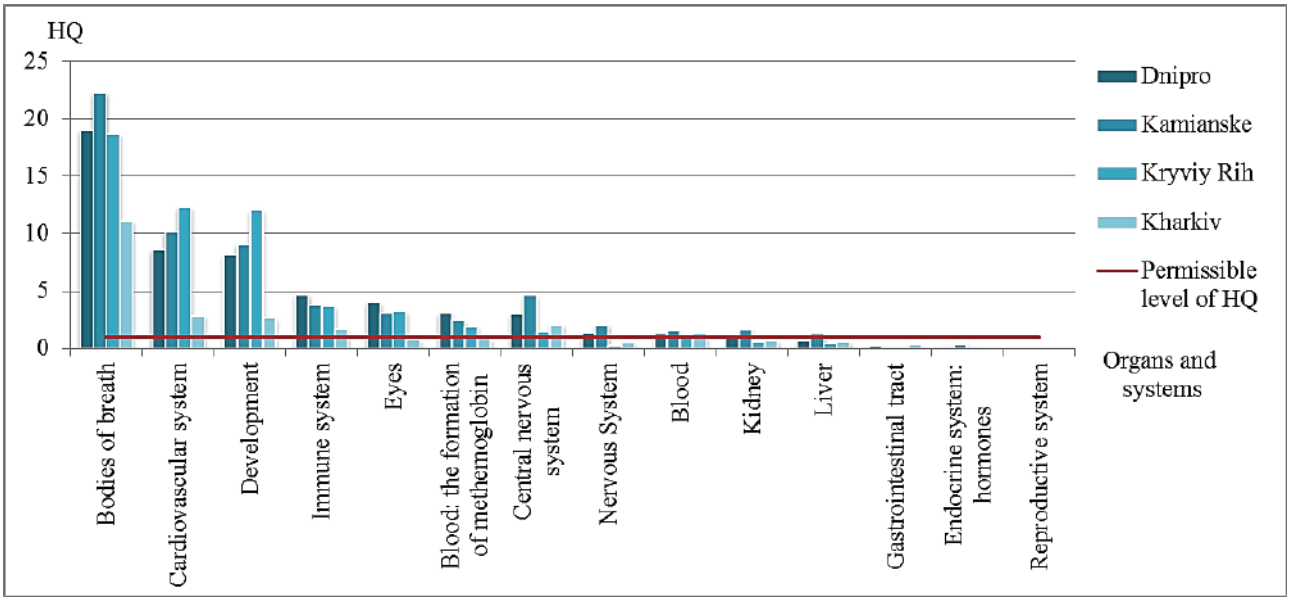

Fig. 3. Risk of development of non-carcinogenic effects from pollution of atmospheric air in organs and systems of the body

chromium. The assessment of carcinogenic risk, CR, was carried out in accordance with the generally accepted methodology (Rukovodstvo po ocenke riz dlja zdorov'ja naselenija pri vozdejstvii himicheskih veshhestv, zagrjaznjajushhih okruzhajushhuju sredu, 2004), described above (Table 1).

Table 1. Assessment of carcinogenic risk from polluted air (2014 – 2016)

№	Carcinogen	Dnipro	Kamianske	Kryviy Rih	Kharkiv
1	Formaldehyde	1,58E-04	1,23E-04	1,27E-04	3,07E-05
2	Cadmium	5,40E-06	1,02E-05	4,81E-06	–
3	Nickel	4,49E-06	4,80E-06	3,19E-06	6,40E-06
4	Lead	2,84E-07	3,20E-07	2,40E-07	4,40E-07
5	Chromium	2,52E-04	1,60E-04	1,60E-04	3,60E-04
CR total		4,20E-04	2,98E-04	2,95E-04	3,98E-04
Assessment of CR level			Conditionally acceptable		Acceptable

The obtained carcinogenic risk values from atmospheric air pollution are classified into two categories: conventionally acceptable level of risk and acceptable risk level. The lowest carcinogenic risk corresponding to an acceptable level is characteristic of lead. The greatest contribution to the total carcinogenic risk is made by the pollutants: chromium– from 53.6 to 90.6%; formaldehyde – from 7.7 to 43.1% (Fig. 4). Such a distribution is likely to be due to the preponderance of stationary sources of pollution over motor vehicles, which is one of the main factors of lead pollution of the environment

Thus, the carcinogenic risk from atmospheric air pollution in the cities of Kharkiv and Dnipropetrovsk regions corresponds to the permissible level. However, given the limited list of chemicals and elements whose content is subject to atmospheric air monitoring within the studied area, the actual carcinogenic risk is likely to be higher. In particular, there is no ongoing monitoring of the soot content in Dnipropetrovsk oblast and in most other regions of Ukraine – the equivalent of PM2.5 according to the international classification, which is a carcinogenic pollutant.

Conclusions

1. Assessment of atmospheric air pollution hazard within the settlements of Kharkiv and Dnipropetrovsk regions was carried out within the framework of the research on the criterion of environmental risks, namely, the risks of carcinogenic and non-carcinogenic effects on the population.

2. The total non-carcinogenic risk from atmospheric air pollution within the studied cities exceeds the permissible level. The range of non-

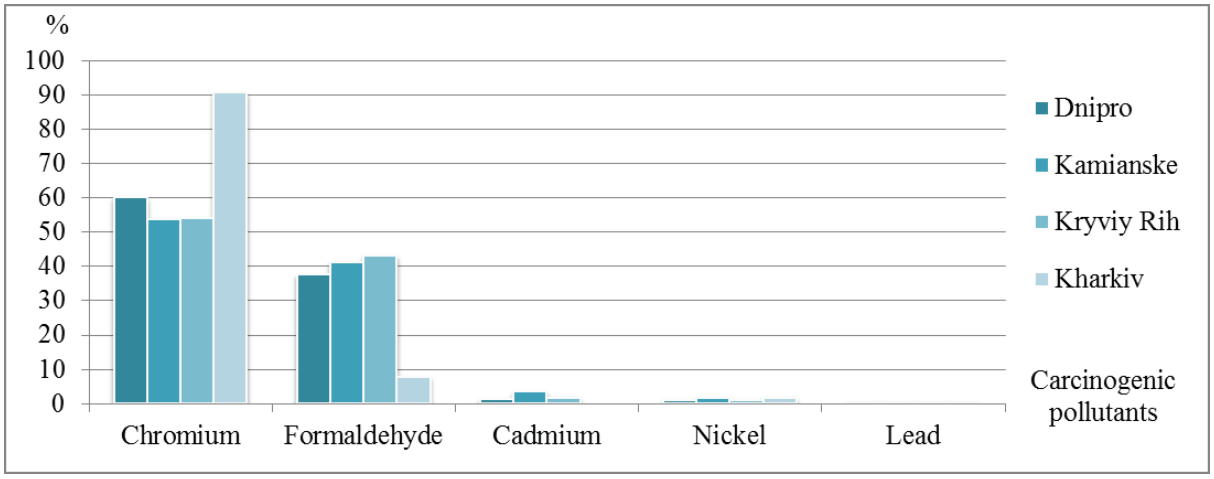

Fig. 4. Distribution of contributants of contamination to total carcinogenic risk

carcinogenic risk varies from 11.9 to 23.3 HQ. The greatest danger is the pollution of air by $PM_{2.5}$, copper, formaldehyde, nitrogen dioxide, manganese and phenol.

3. Pollution of air within the studied cities, above all, is associated with the risk of harmful effects to the respiratory system, blood, eyes, cardiovascular and immune systems, central nervous system, as well as disorders of the human body in general.

4. The total carcinogenic risk from atmospheric pollution in all cities is characterized as conditionally acceptable,chromium and formaldehyde being the most dangerous pollutants.

5. In view of the obtained results, it is expedient to include assessment of the health risks in the system of monitoring and control of the environment in Ukraine; it is advisable to disseminate information and analytical materials among the population on the impact of major pollutants on the human body, in particular heavy metals.

6. Prospects of further research are related to the assessment of risks to the population from atmospheric air pollution, increase in the number of settlements and regions of research,development of approaches to optimization of the air monitoring system.

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Results of petrographic research of new finds from the archaeological monument Tokivske-1

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Abstract. The purpose of the work was to determine the provenance of the raw materials of ancient stone products, found during the excavations of the Bronze-Early Iron Age monument Tokivske-1, with the aim to establish connections of the ancient population of the area with residents of other regions. The archaeological monument Tokivske-1, located in the northern outskirts of the village Tokivske, Apostolove Raion, Dnipropetrovsk Oblast, has been explored by the expedition of Dnipropetrovsk National Historical Museum named after D.I. Yavornytskyi since 2012. The authors of this article already carried out petrographic study of stone artefacts from this monument, which had been found during the first five years of excavations. However, over the past two years, a number of stone and other items were found that could expand our knowledge of the links of Tokivske-1 with ancient industrial centers of other regions. To carry out the petrographic analysis, six artefacts were taken, mainly those made from macroscopically different rocks. Most of them can be related to metalworking. The analyzed samples are represented by an amphibolite hammer for forging jewels or peening sheet copper, a dolerite anvil-prop for a specified hammer, a fragment of an abrasive stone made of ferruginous quartzite, a quartz tile, which is a fragment of an altar, and fragments of an anvil and a scepter-pestle made of sandstone. Petrographic analysis of artefacts allowed determining the probable provenance of their raw materials. Amphibolites are quite common in the territory of the Middle Dnipro area, but by the color of the hornblende, the predominance of epidotization processes over sericitization and macrostructural features, the studied rock is more similar to the amphibolites from the middle stream of the Bazavluk River. Dolerites, similar to the raw material of the anvil-prop, are also common in the area of excavations, and by the presence of the micropegmatite in its composition, its origin can be localized in the middle stream of the river Bazavluk or in the valley of the river Mokra Sura. Magnetite quartzite – the raw material of the abrasive stone – most likely comes from the territory of the city of Kryvyi Rih. Quartz tile – a fragment of an altar – is a quartz vein, similar to those that intersect granites of the Tokivskyi massif directly near the village Tokivske. Sandstones, from which the anvil and the scepter-pestle were produced, appeared to be very similar in their petrographic features. They are represented by quartz sandstones with fragments of rocks and polymineral cement with the predominance of quartz regenerative and porous sericite cement. Also, the relic chalcedony and, more rarely, clay cement are present in the pores. In the territory of Ukraine, the most similar to them, according to petrographic characteristics, are the sandstones of the Carboniferous system, which crop out in the Donbas. Thus, the obtained data testifies to the connection of the Tokivske-1 archaeological complex with other parts of the Middle Dnipro area, such as the middle stream of the Bazavluk River and the Kryvyi Rih area, as well as with more distant regions such as the Donbas. It should be noted that scepter-pestles, similar to the one studied by us, are associated with metalworking, and the Donetsk basin, where the raw material of the indicated tool originates from, was the copper production center of the Late Bronze Age.

Keywords: petroarchaeology, stone tools, Bronze Age, Tokivske-1

Результати петрографічного дослідження нових знахідок з археологічної пам'ятки Токівське-1

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Анотація. За допомогою петрографічного аналізу визначається походження матеріалу кам'яних виробів епохи бронзи з матеріалів розкопок археологічної пам'ятки Токівське-1, розташованої на північній околиці с. Токівське Апостолівського району Дніпропетровської області. Досліджено шість виробів, знайдених під час останніх археологічних розкопок пам'ятки експедицією Дніпропетровського національного історичного музею ім. Д.І. Яворницького у 2017 – 2018 рр. Більшість із них за функціональним призначенням можуть бути пов'язані з металообробкою. Досліджувана колекція представлена молоточком для кування ювелірних виробів або проковування листової міді, підставкою-ковадлом для зазначеного молоточка, фрагментом абразивного каменя, плиткою – фрагментом жертовника, фрагментом ковадла та фрагментом товкача-скіпетра. Найбільш цікавим з досліджених знарядь був пісковиковий товкач-скіпетр, подібні якому, на думку більшості дослідників, належали майстрам-металургам. Для проведення дослідження були обрані зразки, виготовлені з макроскопічно відмінних порід, які могли мати різне походження. Визначення походження виробів є важливим для встановлення зв'язків археологічної пам'ятки з іншими регіонами, зокрема виявлення торговельних зв'язків з центрами металовиробництва. В результаті виконаного петрографічного дослідження визначено, що матеріал артефактів представлений амфіболітом, долеритом, залізистим кварцитом, жильним кварцом і пісковиком. За допомогою порівняння петрографічних особливостей досліджуваних зразків та зразків, відібраних з природних відслонень, а також за опублікованими і звітними даними, було визначено імовірне походження сировини виробів. Всі досліджувані зразки, окрім пісковиків, мають аналоги серед гірських порід Середнього Придніпров'я, при цьому амфіболіт та долерит, найімовірніше, походять з середньої течії р. Базавлук, а залізистий кварцит – з території Криворіжжя. Можливо, племінне об'єднання доби бронзи, якому належала пам'ятка Токівське-1, займало територію між річками Базавлук та Інгулець. Зразки пісковиків, найімовірніше, походять з території Донецького кряжу, що може свідчити на користь зв'язків Токівського-1 з Донецьким гірничо-металургійним центром доби бронзи.

Ключові слова: археологічна петрографія, кам'яні вироби, епоха бронзи, Токівське-1

Introduction. Petrographic analysis is widely used in modern archeology. It is applied to determine the provenance of the artefacts' raw materials that cannot be done using conventional archaeological methods. Determining the raw materials of stone products can detect the connections between remote areas, establish the facts of the exchange trade between regions, and may help in finding places of ancient mining of stone raw materials.

Most often, petrographic methods are used in the research of polished stone tools, which were widely used from the Neolithic to the Bronze Age. Recently, the materials of research of many such stone artefacts were published in the world literature, particularly stone axes and other tools of the archeological monument Wroclaw-Vidava-17 in Poland (Borowski, 2014), collections of Neolithic polished axes found in the southern Italy near Paestum (Aurino, 2017), basalt artefacts of the Bronze Age from Israel (Gluhak, 2018). One of the most comprehensive studies was the petrographic research of more than 400 polished stone tools and weapons dated to the Middle Bronze Age from central Hungary (Farkas-Pető, 2014). The subject of petrographic research were the altar stones of megalithic monuments as well, in particular, an additional study was recently conducted on the composition and provenance of the altar stone material of the world's most known Stonehenge complex in the United Kingdom (Ixter, 2019).

This article is devoted to the research of new finds of polished tools and constructional elements from the Tokivske-1 archaeological monument. It is located at a distance of 0.23 km from the northern outskirts of the village Tokivske, Apostolove Raion, Dnipropetrovsk Oblast, on the right bank of the river Kamianka, which is the right tributary of the Bazavluk River. Archaeological explorations and excavations on this site have been carried out by the expedition of the Dnipropetrovsk National Historical Museum named after D.I. Yavornytskyi since 2012. Studies in the territory of the monument showed three main cultural horizons. The lower one dates back to the transition period from the Middle to the Late Bronze Age (the cultural circle Babine), with which the creation of the monument is associated. The next layer is the Late Bronze Age (Sabatynivska culture). The upper horizon dates back to the Early Iron Age (Scythian culture) (Starik, 2017).

The authors already carried out a petrographic study of stone artefacts from Tokivske-1, found during the first five years of excavation (Nikitenko, 2018). However, new discoveries in the territory of the complex led to the need in revising the role of the studied monument, particularly as a metal processing center of the Bronze Age. Thus, in 2017, six stone and clay casting molds and their fragments with negatives for casting bronze pins with ball-shaped heads, sickles, needles, chisels, daggers, and socketed axe-celts were found. In 2018, two stone double-sided molds for casting of daggers, a mold with a lid for casting round-shaped ingots and a unique four-sided casting mold were also found. Thus, the issues of finding the other evidences of metalworking in the territory of the monument and the establishment of the raw materials sources of supply appeared.

Petrographic study of a number of artefacts, which may indicate the existence of interregional relations, was necessary for solving the formulated problems. To

carry out the research, the artefacts, which origin was of the highest interest for archaeological study, were selected (Tab. 1). Most of them could be related to metal processing. Of special interest was the provenance of the raw material of the stone scepter-pestle (Fig. 1), since such instruments are quite rare and are related to the centers of metal processing in Eastern Europe and Central Asia. According to Boroffka and Sava it belongs to the type Ia, widespread from the Volga to the Danube River, mainly in the territory of Ukraine and Moldova (Boroffka, 1998).

Table 1. The list of studied stone artefacts

No.	Name	Inventory number	Measurements, cm	Material
1.	Working tool (hammer for forging jewels or peening sheet copper)	86	7 x 5.5 x 5	Amphibolite
2.	Anvil-prop for forging jewels or peening sheet copper	305	11.5 x 7 x 6.5	Dolerite
3.	Abrasive stone (fragment)	none	4 x 4 x 4.5	Ferruginous quartzite
4.	Tile (fragment of an altar)	none	6 x 12 x 8	Vein quartz
5.	Anvil (fragment)	none	7 x 6.5 x 6	Sandstone
6.	Scepter-pestle (fragment)	152	7.2 x 5 x 7.5	Sandstone

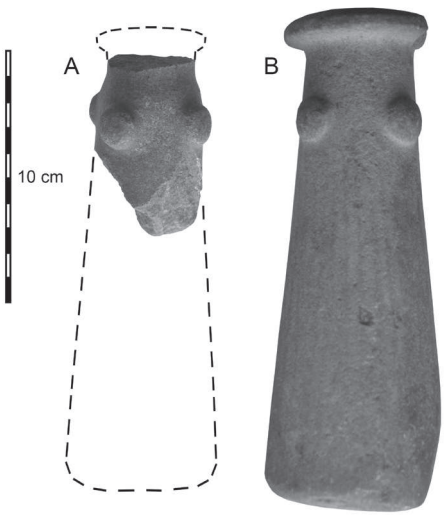

Fig. 1. Scepter-pestles of the Bronze Age.
A – studied fragment of the pestle from Tokivske-1 (sample 6); B – intact sample from the museum collection.

The purpose of the work is to determine the provenance of the materials of the Bronze Age stone artefacts that were found during the excavations of Tokivske-1 in order to establish connections between the monument and other regions.

Materials and methods. Microscopic research of thin sections was carried out using polarizing microscope LOMO POLAM R-312. The origin of raw materials of the artefacts was determined by comparative petrographic analysis with samples of similar rocks from the Middle Dnipro area and other regions. Similarly, the comparison was performed with the thin sections produced from the materials of other archaeological artefacts, which origin was established during previous studies. In addition, the data from the reports of primary geological survey and literary works of the mid-twentieth century were used, which provided a detailed petrographic description of rocks from natural exposures, since ancient miners could only use rocks that occur close to the day surface.

Results and their analysis. As a result of mineralogical and petrographic analysis of six artefacts it was established that they were made from amphibolite, dolerite, magnetite quartzite, vein quartz and sandstone (Tab. 1).

Amphibolite (sample 1) is represented by a fine-grained rock, in which the femic mineral – hornblende

– contrastingly stands out against the background of a lighter salic mineral – plagioclase. Mineral composition of amphibolite (vol. %): hornblende – 50 – 55; plagioclase – 45 – 50; quartz, epidote, opaque mineral, sphene – less than one percent. Hornblende forms tabular crystals of light green color with rhombic amphibole cleavage. It demonstrates pleochroism from green-yellow to turquoise-green with brown-green spots. The size of crystals is 0.5 – 2.0 mm, mainly 1.0 – 1.5 mm (Fig. 2). Plagioclase is represented by crystals of a tabular and irregular shape (conformal boundaries) with polysynthetic twins. The size of the plagioclase crystals is from 0.5 to 1.5 mm, the mineral is weakly sericitized. Quartz forms crystals of isometric shape up to 0.2 mm in size. In contrast to plagioclase, it is transparent and has no impurities of secondary minerals. The epidote is contained in the form of crystals of irregular and tabular form in the size up to 0.2 mm with anomalous interference colors. Usually, the crystals of epidote form aggregates. The mineral replaces the hornblende, less – plagioclase. The opaque mineral is represented by angular crystals. Several grains on the edges are translucent in red, which makes it possible to relate the opaque mineral to hematite. Sphene in the studied amphibolite forms isometric crystals that differ in the thin section with a high refractive index and interference color. Sphene is surrounded by aureoles of secondary alteration products with lower refractive index (epidote?). The main minerals of the amphibolite are gathered into aggregates, therefore its texture can be defined as glomerogranoblastic.

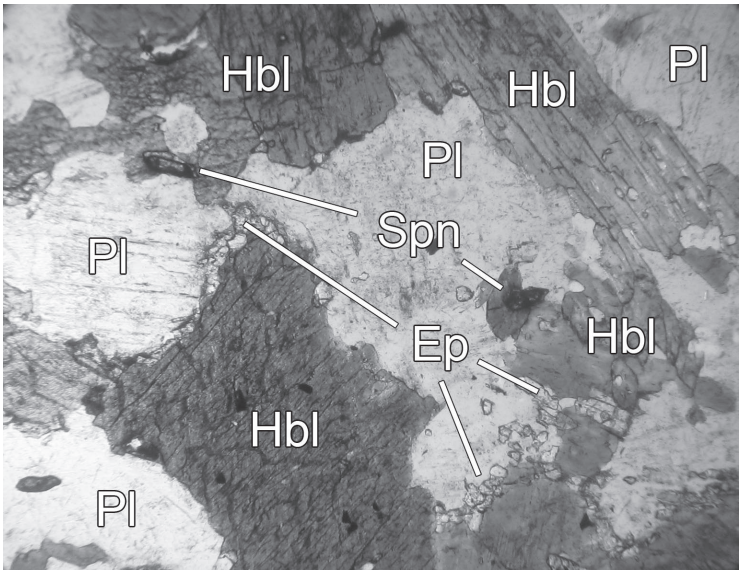

Fig. 2. Amphibolite (sample 1).
Hbl – hornblende; Pl – plagioclase; Ep – epidote; Spn – sphene. *Transmitted light, nicols (–), x 47*

Provenance. Amphibolites are common rocks in the Middle Dnipro area; also, they are exposed in the North Azov Sea area, the Bug River area, in the Inhulno-Inhuletskyi and Rosynsko-Tikytskyi areas of the Ukrainian Shield (Yesypchuk, 2004). The biggest outcrops of amphibolites are located in the Kryvyi Rih area and in the right-bank part of the Middle Dnipro area in the valleys of the rivers Bazavluk, Mokra Sura, Chortomlyk and their tributaries. The analyzed sample differs from the Kryvyi Rih amphibolites, exposed in the valleys of Saksahan and Inhulets rivers, by the shape of hornblende crystals and lack of biotite; from Saksahan amphibolites it also differs by the presence of twins in plagioclase. According to Usenko, amphibolites of the right-bank part of the Middle Dnipro area, which form natural outcrops, are divided into two groups: amphibolites of the middle stream of the river Bazavluk and the group of amphibolites of the lower stream of the Bazavluk River (Sholokhove village), Chortomlyk River and the river of Mokra Sura (Usenko, 1953). At all of these occurrences the varieties of amphibolites, which have common features with the analyzed sample, crop out. But, taking into account the predominance of epidotization (as opposed to the sericitization that is typical for Sholokhove amphibolites), lighter, spotty color of hornblende, high content of plagioclase, macrostructural features (dark crystals of hornblende stand out against a background of light-gray plagioclase), the studied sample is more similar to the amphibolites of the middle stream of the river Bazavluk. The comparative petrographic analysis of amphibolites from this

area and the raw material of the analyzed tool showed the greatest similarity to the sample we picked up at the rocky outcrop in the village Udachne in the middle stream of the river Bazavluk.

Dolerite *Provenance.* Dolerites (diabases) are quite common in the territory of the Middle Dnipro Megablock of the Ukrainian Shield. Fresh olivineless species form natural outcrops along the river Bazavluk, in the middle stream of the river Bazavluchok, as well as in the southern part of the Mokra Sura River and the river Dnipro. We investigated a similar rock in the valley of the river Mokra Sura. The peculiarity of the raw material of the artefact is the presence of micropegmatite, which is the intergrowth of feldspar and quartz. Similar inclusions were noted by Usenko in pyroxene diabases, which are exposed on the river Mokra Sura and between the tributaries of the river Bazavluk – the gullies Krynychevata and Bakulin Brid (Usenko, 1952).

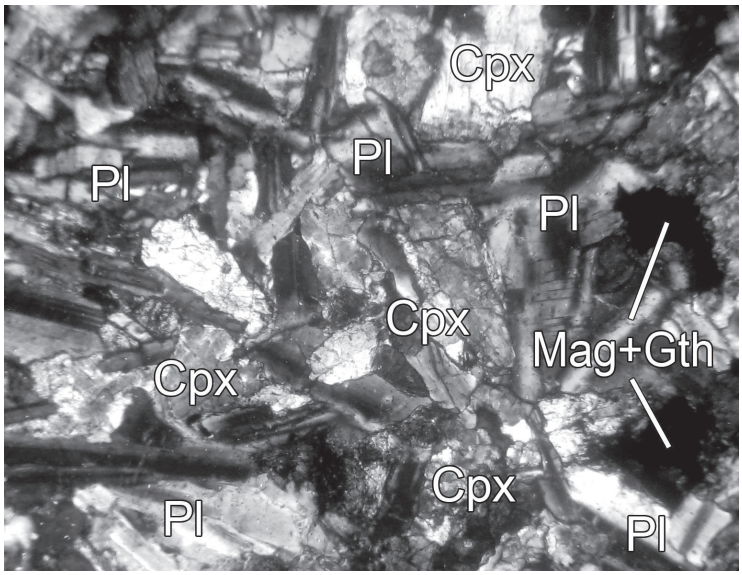

Fig. 3. Dolerite (sample 2).
Cpx – clinopyroxene; Pl – plagioclase; Mag+Gth – magnetite and goethite. *Transmitted light, nicols (+), x 90*

Ferruginous quartzite (sample 3) is represented by a dark grey, fine-grained rock. The examined sample is magnetic, the ore layers have a black streak. The rock consists of parallel substantially ferruginous and substantially quartz layers up to 1 cm thick. A study of the rock under a microscope showed that the ferruginous layers contain less than half the volume of quartz, and the quartz layers contain up to 10% of linearly located grains of an ore mineral. The size of quartz and ore mineral crystals is 0.05 – 0.3 mm. Between crystals of quartz there are aggregates of flakes of a transparent mineral of the group of sheet silicates with straight extinction and higher than quartz interference colors, probably, talc, which could replace a mineral of the cummingtonite-grunerite series (Fig. 4). Goethite is represented by single large grains, as well as a disperse admixture that tinctures the sericite flakes and fills the gaps between quartz grains. As a result of the polished section analysis, it was determined that the ore mineral crystals are represented by one mineral species with the same reflectance, which is shown by all aggregates. Considering the results of macroscopic and microscopic study, the rock can be defined as a magnetite quartzite.

Provenance. Ferruginous quartzites are widespread in the territory of the Ukrainian Shield inside numerous iron-siliceous formations, most of which are covered with sedimentary rocks. The outcrops, sufficient for surface development in ancient times, are located along the Inhulets and Saksahan rivers (modern Kryvyi Rih basin) and at the Korsak-Mohyla deposit in the North Azov Sea area (Usenko, 1975). Taking into consideration the proximity of the place of the sample finding to Kryvyi Rih, most likely, the raw material of the tool originates from there.

Vein quartz (sample 4) is represented by a tiled sample obtained as a result of a thin quartz vein separation from the adjoining granitic rock. The investigated sample is composed of coarse-crystalline quartz. Between quartz crystals, the crystals of feldspar (microcline and plagioclase) are located, which make up to 5 % of the volume of the rock. Plagioclase is replaced by secondary sericite. The size of quartz crystals – up to 10 mm, feldspar – up to 1 mm. The texture of the rock is heterogranoblastic.

Provenance. The veins of quartz intersect pink granites of the Tokivskyi massif in the area of the excavations. Similar mineral bodies were observed by the authors in rocky outcrops of granites in the valley of the river Kamianka.

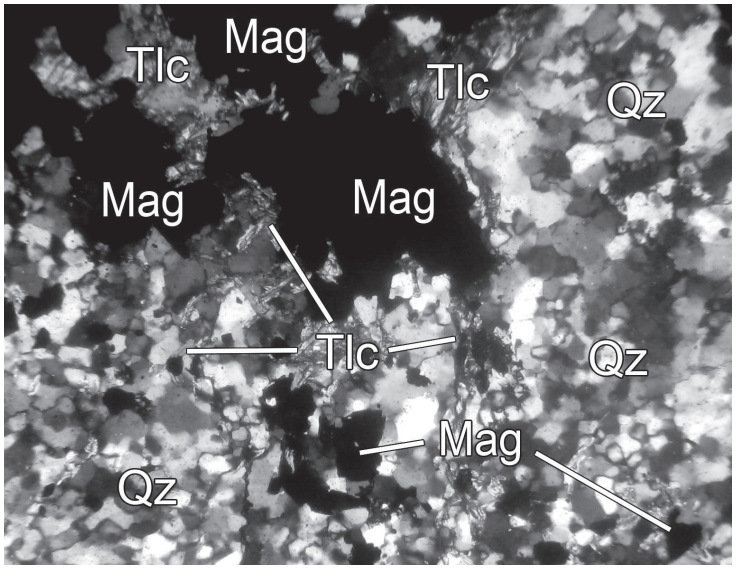

Fig. 4. Ferruginous quartzite (sample 3).
Qz – quartz; Mag – magnetite; Tlc – talc. *Transmitted light, nicols (+), x 90*

Sandstone in the collection is represented by two samples with similar mineral composition and lithological features (samples 5 and 6). Both rocks can be defined as quartz sandstones with polymineral cement.

The ratio of clastic material and cement in the sandstone is nearly 95 to 5. Composition of clastic grains (% of clastic material): quartz – 97; chert – up to 2; feldspars and microquartzite – less than a percent (Fig. 5). It should be noted that the sample 5 differs from the other by lower content of clastic grains of chert, as well as the presence of single flakes of muscovite in the thin section. Quartz is represented by grains with conformal boundaries formed as a result of dense compression. The size of the fragments is 0.2 – 1.4 mm, mostly 0.3 – 0.5 mm. The regenerative cement encircles many of quartz grains. Chert is mainly represented by semi-coarse isometric grains with the size of 0.2 – 0.4 mm, formed by a micro-flaky aggregate of chalcedony, and sometimes also contains admixture of hydromica flakes (siliceous slate). Crystals of feldspar are close in size to quartz grains and differ from the latter by intensive alteration with sericite. Possibly, some individual aggregates of sericite were

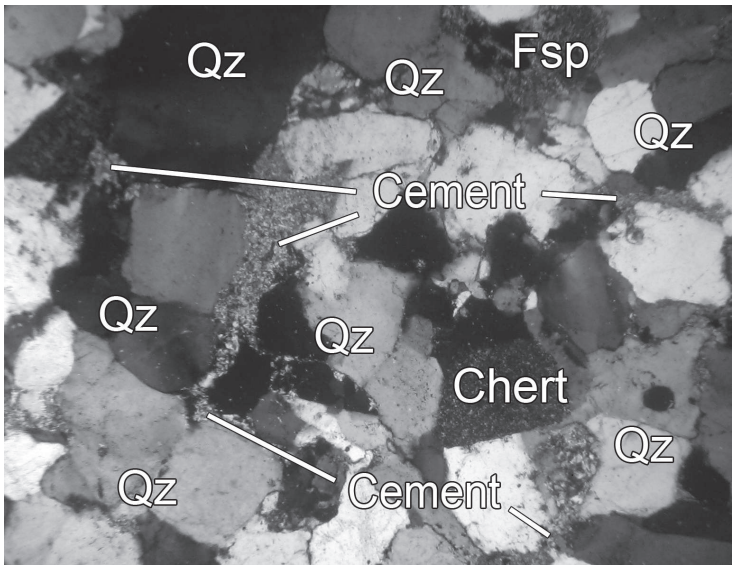

Fig. 5. Sandstone (sample 6).
Qz – quartz; Fsp – sericitized feldspar; Chert – fragment of chert; Cement – sericite and chalcedony cement.
Transmitted light, nicols (+), x 47

formed due to the replacement of feldspars.

Cement of the sandstones has a polymineral composition with a predominance of sericite and regenerative quartz cement. In general, the most of clastic grains are connected without cement (dense arrangement) or have thin rims of quartz regenerative cement around. Relic cement is contained mainly in pores, sometimes it forms thin interlayers between clastic grains. Porous cement is represented by the micaceous (sericite) and siliceous (chalcedony) types. Sericite cement fills pores as well as it is contained in small quantities between clastic grains. Chalcedony cement is represented by a micro-flaky aggregate that fills the pores (Fig. 6). In both samples, the two types of cement may coexist in one pore. In the sample 5, in some pores, the zones of kaolinite cement are also contained. Also, there are aggregates and disperse admixture of goethite in the cement. The texture of both samples of sandstone is psammitic.

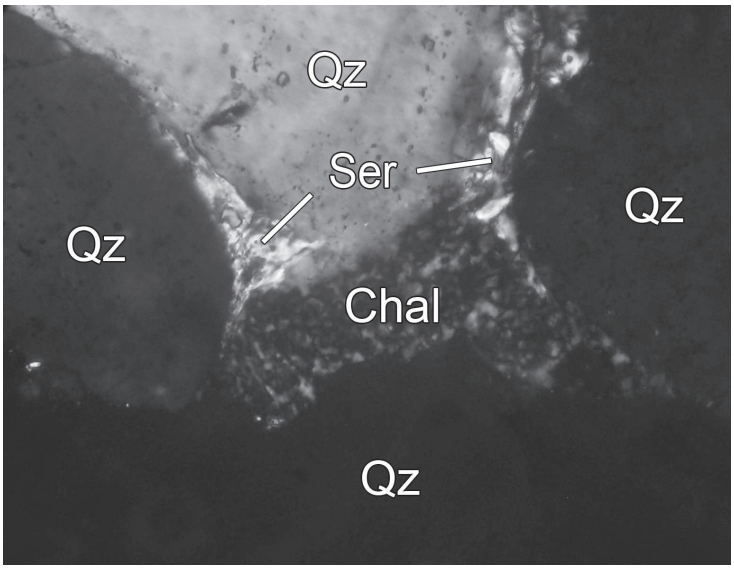

Fig. 6. Sandstone (sample 6).
Qz – quartz; Ser – sericite cement; Chal – chalcedony cement. *Transmitted light, nicols (+), x 400*

Provenance. Similar varieties of sandstones are not typical for the Middle Dnipro area. (Tkachuk, 1981; Vidergauz, 1964). Sandstones of the late stage of catagenesis are characteristic for geosynclinal structures. In the territory of Ukraine the nearest occurrences of the rocks that are similar in petrographic features are located in the Central Donbas, where Carboniferous quartz sandstones, which contain debris of rocks (mainly chert), muscovite, have regenerative quartz, sericite-siliceous and kaolinite cement, crop out (Tkachuk, 1981). Similar rocks are also common in Podilia as a part of the Yampil layers of the upper Vend, but these sandstones are more catagenetically altered, they contain significantly less debris of sedimentary rocks and practically do not have relic cement, which is composed of sedimentary minerals. Based on this, we are inclined to regard the raw materials of the investigated tools as a Donbas Carboniferous sandstone.

Thus, based on the petrographic study, it was established that the most of analyzed artefacts were made from the rocks that are common in the Middle Dnipro area – the region of excavations. The amphibolite of sample 1 has close analogues among the rocks, which are exposed in the middle stream of the river Bazavluk. From there the dolerite of the sample 2 may also originate. Ferruginous quartzites, similar to the sample 3, are most common in the Kryvyi Rih area, where they crop out in the valleys of the rivers Inhulets and Saksahan. The quartz of the sample 4 is found in the form of veins that intersect the granites of the Tokivskyi massif in the village Tokivske. Only the sandstones of specimens 5 and 6 have no analogues among the rocks of the Middle Dnipro area, and the most similar rocks to them are the Carboniferous sandstones of the Donets Basin.

Based on the obtained data, we can make assumptions about a certain ethnic homogeneity and close trade and cultural connections of the population of the Bronze Age, which lived in the territory of the Bazavluk and Inhulets rivers' basins in the Middle Dnipro area, who created and used the archaeological monument Tokivske-1. Probably, there lived a tribal union in these territories, and the Tokivske-1 belonged to one of its centers. The production of the scepter-pestle from the sandstone, which most likely originates from the territory of the Donets Ridge, may

indicate the connection of the monument with the Donets Mining and Metallurgical Center of the Late Bronze Age, where the development of copper ores was carried out within the Bakhmut Basin (Brovender, 2007). It is also necessary to take into account the assumption that similar scepter-pestles belonged to masters-metallurgists who enjoyed a high status in the contemporary society. In the petrographic study of stone tools of ancient miners and metallurgists, found during excavations at the Kartamysh deposit (Luhansk Oblast), one of the authors established the origin of a considerable number of them from the Middle Dnipro area, in particular casting molds (Nikitenko, 2010). Thus, the obtained data once again testifies in favor of the existence of an ancient trade route, which connected both regions.

Conclusions. As a result of the study, the list of rocks that were used as raw materials for the production of tools and for the construction of cult objects in the territory of the archaeological monument Tokivske-1 was expanded. In particular, taking into account the data of previous studies, in the Bronze Age, such rocks as granite, amphibolite, dolerite, metadolerite, quartzite, quartz-zoisite-actinolite schist, pyroxene quartzite, magnetite quartzite, vein quartz and sandstone were used. Most types of stone raw materials have analogues among the rocks that exposure directly in the village Tokivske or, most often, near the neighboring village Sholokhove. Among the investigated artefacts, not of local origin are the samples made of amphibolite and dolerite similar to those, which crop out in the middle stream of the Bazavluk River, as well as those made from magnetite and pyroxene quartzites, which most likely originate from the Kryvyi Rih area. Two artefacts made of sandstone, which is not typical for the Middle Dnipro area, are most likely to come from the territory of the Donets Ridge. This fact indicates the possible trade relations of Tokivske-1 with that region.

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Geological and geomorphological and historical components of the rock monasteries of the Middle Podnistrovia

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Abstract. The paper describes a combination of lithological basis and foundation of cave monasteries of the Middle Podnistrovie. This combination resulted in specific integrated geohistorical monuments (geosites). In the steep rocks of the canyon-like valley of the Dniester, in the process of Christianity, numerous individual or communal caves have been made. Nowadays, only three have remained and continue to be used for their original religious purpose: Bakota, Neporotovo, and Liadova cave monasteries. The place for foundation was not randomly chosen and was conditioned by several factors, the essential ones being geomorphological and sacred aspects. The geologic-geomorphologic factor was determined by presence of high and almost inaccessible rocks that allowed solitude and relative security for the inhabitants from raids of non-Christians. Not the last role belonged to the rocks, in which using simple tools, caves could be cut and rooms organized. It was determined that Bakota rock monastery was founded in opokas of Cenomanian stage, which were highly porous, and were malleable for processing. The tortuous route above the caves of the Bakota monastery was made in solid Sarmatian limestones along the denudation fractures widened by karst processes and by tools. Neporotovo cave monastery has mixed natural-anthropogenic origins and was initiated by karst-suffusion processes in the oolite Sarmatian limestones. Liadova cave monastery as well as Bakota cave monastery were cut from Cenomanian deposits, but in carbon facies, in which Cretaceous-like limestones dominate , which are malleable for making passageways Hydrogeological conditions were important for the building of the monastery, particularly, presence of drinking water. The sacred component was conditioned by religious canon laws and traditions. Each of the studied monasteries has a complex, and often tragic history recorded in archeological materials and archive documents, but the greater part of their thousand years history remains unknown.

Key words: rock monastery, Middle Podnistrovia, geological structure, lithogenic basis, geohistorical monuments

Геолого-геоморфологічна та історична складові скельних монастирів Середнього Подністров'я

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Анотація. У представленій статті висловлюється припущення про закономірне поєднання літогенної основи і закладання скельних монастирів Середнього Подністров'я. Наслідком цього зв'язку є існування специфічних інтегрованих геоісторичних пам'яток (геосайтів). У прямовисних скелях каньйоноподібної долини Дністра з поширенням християнства стихійно закладались чисельні усамітнені чи колективні печерні обителі. Нині збереглися і продовжують функціонувати за призначенням лише три: Бакотський, Непоротівський та Лядовський скельні монастирі. Вибір місця для закладання монастиря був не випадковим і зумовлювався кількома факторами, серед яких ключова роль належала геолого-геоморфологічному та сакральному. Геолого-геоморфологічний фактор визначався наявністю високих і важкодоступних скель, які давали можливість для усамітнення та відносної безпеки обителі при частих набігах іновірців. Не останню роль відігравали і гірські породи, в яких нехитрим ручним інструментом можна було прорубати келії і облаштувати відповідні приміщення. Встановлено, що Бакотський скель-

ний монастир закладений у опоках сеноманського ярусу, які, будучи високопористими, легко піддаються обробці. Звивистий хід над печерами Бакотського монастиря прокладений у міцних вапняках сармату по денудаційним тріщинам, розширених карстовими процесами і людською рукою. Непоротівський скельний монастир має змішане натурально-антропогенне походження і зініційований карстово-суфозійними процесами в оолітових вапняках сармату. Лядовський скельний монастир, як і Бакотський, закладений у сеноманських відкладах, але у карбонатній фації, в якій домінують крейдоподібні вапняки, що податливі для прокладання штучних ходів. Важливе значення в монастирському будівництві мали гідрогеологічні умови, зокрема, наявність джерел питної води. Сакральна складова була зумовлена релігійними канонами і традиціями. Кожний з досліджених монастирів має свою складну й, нерідко, трагічну історію, зафіксовану в археологічних матеріалах та архівних документах, однак більша частина їх тисячолітньої історії залишається невідомою. У представленій статті висловлюється припущення про закономірне поєднання літогенної основи і закладання скельних монастирів Середнього Подністров'я. Наслідком цього зв'язку є існування специфічних інтегрованих геоісторичних пам'яток (геосайтів).

Ключові слова: скельний монастир, Середнє Подністров'я, геологічна будова, літогенна основа, геоісторичні пам'ятки

Introduction. The Middle Podnistrovia is rich in various natural geological monuments which owe their existence to the peculiarities of the geological structure of the region and favourable conditions for the outcrops of rocks created by the erosion activity of the Dnister river. Along with this, the Middle Podnistrovia was inhabited from ancient times by people who left a variety of items of material culture, many of which can now be regarded as archaeological, architectural, or other historical monuments. These monuments include rock monasteries located on the cliffs of both banks of the Dniester river.

The choice of location for future rock monasteries was not accidental and depended on a number of factors, not least among which was the geological factor. Therefore, there was a certain natural combination of natural and religious components. Therefore, the objective of the present study was a comprehensive natural and cultural-historical assessment of cave monasteries of the Middle Podnistrovia and the identification and analysis of patterns of this combination.

Materials and methods of research. From the geological point of view, the Middle Podnistrovia region has been studied quite fully and comprehensively, as evidenced by numerous publications (Geologicheskaya, 1982; Geologicheskaya, 1993; Denisik, 2014) on the stratigraphy of the Vendian, Cambrian, Ordovician, Silurian, Devonian, Cretaceous Neogene and Quaternary deposits, the study of various fossils and traces of life, paleogeography, the geomorphology of the river valley and the history of its formation. But the question of the combination of natural and historical components in the construction of cave monasteries has up to this time remained outside the field of view of scientists, which is obviously due to the highly specialized focus of these studies. A schematic and incomplete assessment of geological monuments is given in the guidebook "Geological Monuments of Ukraine" (Korotenko, 1985). More was expected from the official and authoritative, bright, well-illustrated multi-volume publication of the same name ,"Geological Monuments of Ukraine" (Bezvynnyy, 2006; Bezvynnyy, 2007). However, it does not mention rock monasteries at all. When giving recommedations on the protection of caves in Nahoriany village, mention was made only of the monastery in Liadova village, but without any description (Bezvynnyy, 2007, p. 25). Scant information about the cave monasteries of the region is scattered in separate special publications, the most wide ranging of which is "Cave Monasteries, Sketes and Cells in the World and Ukraine" (Dymytriy, 1995). The most complete, from the geological perspective, rock monasteries are described in the work "Rock Monasteries of the Middle Dniester as Complex Geological and Cultural-historical Monuments" (Korinnyy, 2008). A comprehensive approach to the study of natural monuments, such as cave monasteries and history, will allow us to more fully assess their scientific, educational, cognitive, aesthetic and recreational significance, as well as to find more rational and effective ways of protecting them.

Our main task was conducting a comprehensive study of rock monasteries, assessing the natural and cultural-historical components that influence their location, to develop recommendations for their further preservation .

Results and their analysis. In the middle flow of the Dniester river, the best preserved and the most famous are the Bakota, Neporotovo and Liadova male rock monasteries. Less well known and almost unexplored are the Sokiletsky and Subochskyi monasteries. There are also about a dozen caves or their remnants, the cultic purpose of which is clearly proven (Dymytriy, 1995; Ridush, 2001). It is unknown how many such structures were destroyed as a result of natural landslides, intentional or accidental human actions. Let us dwell on the natural and cultural-historical appraisal of those rock monasteries that can still be saved from further destruction.

Bakota St. Michael's Male Cave Monastery is 3 km west from the Goraivka village, Kamenets-

Podilsky district of Khmelnytskyi Oblast in the Monastyrysky tract. The monastery is located in the middle of Bila Hora (White Mountain), a 120-meter-high scarp which towers above the surface of the Bakota Bay of the Dniester reservoir. Bakota village itself, which in historical times was a thriving city – the center of the Ponyzzia (Dniester Podillya) – and which gave the name of the monastery, is now gone. It disappeared under the waters of the reservoir.

From the geological perspective, Bila Hora is interesting in itself, as an outcrop, in which depositions of different age stratigraphic horizons are represented. The mountain itself, being part of the Dniester canyon, is a geomorphological monument.

From the shoreline, in ascending order, deposits of the Kanylivska Suite, the Molodovosky Horizon of the Ordovician, the Cenomanian and Sarmatian Stage of Cretaceous and Neogene can be seen as outcrops.

Deposits of the Kanylivska Suite are from the end of the Vendian stage of Podolia's geological development (Stratyhrafiya, 1971). However, on Bila Hora only the tops of the Suite reach the surface; the rest is flooded with water. The outcropped part of the Kanylivska Suite is composed of a thin layer of siltstones and schist argillites of greenish-grey, grey and dark-grey colours.

A subject of considerable interest is Ordovician deposits, which in Ukraine have outcrops only in this area. The Ordovician is represented by thin layers of the Molodovovsky Horizon: Horaivsky and Subitsky (Stratyhrafiya, 2013). The Horaivski layers are composed of grey quartzitic (over 90 % of quartz) sandstones, which within Bila Hora have small and uneven thickness, often arise and disappear from the section. A similar bedding, as well as the presence of sandstone pebble in the bed of the overlying Subitski layers indicate an erosive break in the middle of the Molodovsky period. The Subitski layers are represented by grey limestones with a significant (up to 40%) content of organogenic material, which includes segments of the crinoids, fragments of trilobites, bryozoans, ostracods and brachiopods. From the evidence of these fossils, it was found that the Molodovsky horizon belongs to the lower half of the upper division of the Ordovician system, and a stratigraphic break between the Ordovician and the Silurian in Podillia corresponds to the entire Ashgilian and almost entire Llandovery stages (Stratyhrafiya, 1972).

Deposits of the Cenomanian Stage are the most significant in the structure of Bila Hora. With a great stratigraphic mismatch, they are embedded on the eroded deposits of the Ordovician and have a very variegated lithological composition. These deposits begin with quartz-glauconite fine-grained sands, in which there occur occasional single sandy yellow primary phosphorites, phosphatized spicules of sponges, teeth of fish and other organic matter. The colour of the sands is green or yellow-green. Higher up, there are various rocks, the common feature of which is the high content of silica, which related to the fact that a large number of sponges with flint skeleton lived in the shallow Cenomanian Sea. Among such silicites, there are distinguished (Stratyhrafiya, 1971) flinted sandstones (gaizes), spongolites, opokas [Opoka (Polish) – silicic microporous sedimentary rock – *Translator`s note*], chalcedonys, flint. Most significant among the Cenomanian Stage silicites of Bila Hora are the opokas which are clearly distinguished among others by a continuous several meter thickness. It was in such opokas that human hands almost a thousand years ago carved the cave-cells of the Orthodox rock monastery. The opokas of this place are characterized by light weight, high porosity and malleability in processing. They are light yellow or grey-white and consist of siliceous substances mixed with chalcedony, glauconite and quartz. Silicites are covered by glauconite-quartz sands with sandy yellow phosphates, phosphatized mollusc nuclei and traces of life of burrowing animals. The section of the Cenomanian Stage terminates with the boulder-like chalcedony stones with the foraminifera fauna.

Above the Cenomanian layer, a thick layer of limestones of the Sarmatian Stage of the Neogene is embedded. Limestones are represented by oolites and oolith-detritus and have a whitish-grey or yellowish colouration. The limestones are quite solid and form a high sheer wall below the peak with a slightly wavy surface and smoothed edges. Obviously, due to the bright colour of this sheer part, the whole mountain was named Bila (White). The limestone layers are broken by transverse fractures, in one of which a vertical spiral passage was made, which perhaps forms the upper level of the Bakota monastery.

In the Cenomonian horizon, springs of groundwater originate. Today there are three high flow springs which have long been considered to be healing. Laboratory analysis indicates that anions of chlorides and sulfates predominate in the water content. For example, in spring № 1, amount of chlorides was 27.25 mg/l, sulfates – 46.50 mg/l; the water is characterized by a weak alkaline reaction (pH equaled 7.30) and has a high level of hardness (8.6 mEq/l) (Korinny, 2008).

From the geomorphological perspective, the area around the monastery is also interesting, particularly

the widened area of the Dniester canyon, where Bakota Bay formed when the Dniester was flooded. The bay with an area of about 850 ha has a horseshoe-like shape with a bend towards the north. From the moment of its creation as a result of man-made activity, it has become a food base for a number of local birds and a place of rest for many migratory species. On its banks, rare shoreline-aquatic plant groups are distributed. Due to the uniqueness of the valley landscape, and also well as its important role in biodiversity conservation in 2004, Bakota Bay has been included in the List of Wetlands of International Importance, protected under the Ramsar Convention (Pryrodno-zapovidnyy).

It is impossible to overestimate the historical-cultural significance of this area. Before the flood, the territory was studied in detail by archaeologists. They discovered a number of ancient monuments (Davydenko, 2006). Thus, at the foot of Bila Hora, flint tools of the late Paleolithic were found. In the Monastirsky tract, the remnants of a large Trypillian settlement of the III-II centuries BC were studied. Not far from the present monastery, archaeologists investigated a large mound-like embankment with a stone ring in the center. It was determined that the structure was a sacrificial altar, erected in the late Bronze Age by the local agricultural community which worshiped the sun. In the vicinity of Bila Hora, remnants of Chernyakhiv culture have been found, which date back to the first half of the 1st century BC and the remains of early Slavic settlements.

The historical continuation of the ancient settlements was the ancient Rus town of Bakota, which was located on the site of the present Bakota Bay. In the territory of the ancient town, remains (Davydenko, 2006) of iron workshops, pottery and women's glass jewelry were found. According to the chronicle, during pre-Mongol times, Bakota was the center of social and political life, a significant strategic point of the Dniester Ponyzzia. In the radius of 15 km from Bakota, 31 settlements and 75 villages of the XI-XIII centuries were discovered. In Bakota, among other medieval attributes of a town, there was a feudal castle which was destroyed by the Mongol-Tatars in 1258. At the top of Bila Hora archaeologists have found the remains of ancient earth ramparts and a large stone wall that surrounded the tract from the side of the field. After the defeat of the Mongol-Tatars, the Lithuanian Koriatovich princes conquered the land. They rebuilt Bakota Castle, but as a result of the Polish-Lithuanian war, the castle was destroyed again, never to be rebuilt. Administrative functions passed first to Smotrych, and then to Kamyanets-Podilsky. Since the second half of the XIV, century Bakota gradually lost the status of town, and since the XVI century was mentioned in documents only as a small village. In 1981, it was evacuated and flooded with the waters of the Dniester Reservoir (Horbnyak, 2004).

The creation of Bakota St. Michael's monastery is associated with the functioning of Bakota town, as one of the strongholds of the Galician Principality. The inscription on the wall indicates the consecration of the archangel Michael's monastery and the name of the founder and the first hegumen – Gregory. The palaeography of the inscription indicates (Horbnyak, 2004) that it was made not earlier than the mid-XII century. There is a version (Davydenko, 2006) that the monastery was founded even before the official recognition of Christianity as a state religion. In the mid-XIII century the monastery, simultaneously with the castle located on the mountain, was destroyed. It was rebuilt only a century later, but in the XV century it was ruined again and, due to the expansion of the power of Catholic Poland, the monastery ceased to exist. After the collapse of the rock, the central part of the monastic complex collapsed and became buried in debris.

In the 1980s and 90s, the monastery was rediscovered by V. B. Antonovych, a well-known scientist, Ukrainophile, and a professor of the St. Vladimir University. The archeological expedition under his leadership (Antonovich, 1893) discovered the remnants of the monastery complex, which was on two levels. On the upper level, on the plateau of Bila Hora, in the Sarmatian limestones, a vertical spiral passage was cut with two small cells on the bottom. The connection between this room and the lower level has not been completely determined. The lower level was located approximately at the middle of the mountain. There, V. B. Antonovich discovered three cave buildings, described 17 niches in the walls and 19 tombs in the rock floor (Antonovich, 1886). Also unique frescoes, monastic items and weapons were found.

In 1893 a two-tier wooden church was erected over the remains of the old church with a high pent roof, which was consecrated under the name of the Savior. In 1960 it was destroyed (Davydenko, 2006).

Currently, the territory of the monastery is within the boundaries of the Podilsky Tovtry National Nature Park. By the efforts of the local religious communities and the Park staff the former church and the surrounding area has been brought into some kind of order. From time to time, the monument is visited by tourists, and occasionally religious services

are conducted here. Despite the measures taken, this outstanding cultural-historical monument is threatened with extinction. Atmospheric factors are ruthlessly destroying the soft opoka rock and the overhanging rock may collapse at any moment. Taking into account the constant deficiency of government funds, the most appropriate solution, in our opinion, would be to give the remnains of the monastery to the Orthodox Eparchy. However, there is an idea, that building of a storage pool would slow the natural destruction of the monastery (Korinnyy, 2018). In such conditions, proper reconstruction could be made and therefore the Christian shrine preserved for generations to come.

St. Nicholas Neporotovo Male Monastery is located near Halytsia village, 2 km east of the Neporotovo village in Sokyriansky district of Chernivtsi Oblast. The monastery is located in a steep limestone cape formed by the right bank of the Dniester and the pre-mouth part of the right slope of the Halytsky gully at an altitude of 120 meters from the shoreline of the Dniester reservoir.

The cells of the monastery are located in oolitic limestones of the Sarmatian Stage of the Miocene. On fresh fracture, these limestones are pale yellow or greyish-white in colour and consist of small calcite oolites with additions of fine crushed shell detritus. Macro-palaeontological material appropriate for identification is found rare. Most often in the cores of oolytes, *Foraminifera* from the Quinqueloculina and Elphidium genera are found. Under the influence of atmospheric agents, the limestones have become darker and obtained grey tints.

But, obviously, the most interesting objects from the geological perspective are the elements of karst morphosculpture which can be clearly seen in the bare rocks of the monastery. According to morphology, two forms of morphosculpture can be distinguished: cavities and niches. Cavities are mostly oriented horizontally, which occurred due to their development along the areas of deposits, on which, due to the heterogeneity of the chemical composition of limestone interlayers, selective leaching of calcium carbonate has occurred. The cavities are characterized by fairly flattened walls and internal projections, which, obviously, can indicate the physical washing-out of small underdeveloped particles. The sizes of the cavities range from a few millimeters to a meter or more.

Niches have karst-gravitational origin and have developed, on the one hand, due to the connection of cavities formed by leaching, and on the other hand - by the collapse of the water-sharpened intersections between the caverns. Some niches formed from fractures in the structure of the Sarmatian deposits.

In the ancient times, natural niches were enlarged by people and were adapted for cells. Thus, the cave monastery near Halytsi village has a mixed natural-anthropogenic origin.

The original appearance of the karst morphosculpture can be imagined seeing the rocks in the Halytska Stinka (Galician Wall) Landscape Reserve, which is located near the monastery, only on the opposite side of the Halytsky gully . There are the same karst cavities and niches, which sometimes turn into grottoes and small caves.

By contrast to the wooded Halytska Stinka, both of the rocky terraces of the monastery offer beautiful views of the surrounding countryside, the winding Dniester river, its canyon, the lowland peninsula formed by the meander of the Dniester, on which Neporotove village was built, which gave its name to the rock monastery.

The cultural and historical value of Neporotovo rock monastery is not yet fully determined. Exploring natural recesses in the rocks, archaeologists have found (Isachenko, 2006) traces of prehistoric man: animal bones, the remains of fires. In pre-Christian times, the recesses were used as pagan sanctuaries. In one of them, the remnants of a place of sacrifice were found, dated as early Iron Age.

The exact time when the Christian rock monastery emerged is not defined. It is supposed that it may have appeared at the turn of the XI-XII centuries.

Along the Dniester, apart from the main grouping of 20 caves near Halytsia, concentrated along a 1 km stretch, other groups of caves are located, which were also used as cult Christian structures. On a frieze of one of those caves located on the slope of the Galician ravine, unique and mysterious petroglyphs have been discovered, which have not been reliably identified (Isachenko, 2006). They look like some strange crosses, Greek letters, magic monograms, lines. The only thing that is not in doubt is their great antiquity.

There are very few written evidences of the functioning of the Neporotovo rock monastery as a religious structure. It is known only that before it was devastated by the Turks in the late XVIII century, it was known as the Galician Skete, where protesting monks found shelter. The monastery was restored only in 1904, and from the 1930s it was inhabited by monks, however not for long - the monks were expelled in 1948 when under the new (Soviet) government, and the monastery was desecrated and destroyed. The reconstruction began in 1999, and now it is a unique, fully completed rock-cave natural-architectural complex.

Liadova Saint Useknovensky Male Rock Monastery was located on the south-western edge of Liadova village in the Mohyliv-Podilskyi district of Vinnytsia Oblast. The monastery was located on the left bank of the Dniester river, 0.5 km below the mouth of the Liadova river. The rock, from which the monastery was been cut, and which locals since the old times have called the Tserkovna Hora (Church Mountain), as well as the surrounding area, has great geological and cultural-historical significance .

The geological structure of Tserkovna Hora is best seen in the Church Ravine, which crosses the path to the monastery. A small bridge across the gully was constructed, allowing pilgrims to reach the holy places without hindrance. In the Church Ravine, if one walks to the top along the thalweg, great outcrops of the Vendian Cretaceous and Neogene systems can be seen.

The Vendian deposits are represented there by the Nahorynska Suite formed by the Dzhurdzhivk and Kaliusk layers (Stratyhrafiya, 1971). The Church Ravine is part of the stratotypic section of the Nagoriany Suite. Further on , this section passes the mouth of the Liadova and stretches on to Nahoriany village.

The Dzhurdzhivk layers of the Nagoriany gully are composed of alternation of fine-grained thin sandstones and argillites. Sandstones of these layers often contain fine interlayers of aleurolites and argillites and have mostly grey colours with barely noticeable notable green tint in fresh fractures . The argilites often contain interlayers of aleurolite and fine-grained sandstones and are mostly of green-grey colour.

The Kaluski layers are predominantly composed of mostly motley-coloured, thin argillites which, without much effort, are easily shattered to small sharp-edged fragments. A notable feature of the Kaluski layers is their content of phosphorites. Due to this peculiarity, the Kaliuski layers are a marking horizon. In the Church Ravine, there are single phosphorite concretions that have a spherical or rounded shape and a scabrous surface. In the middle, such concretions have a radial structure and an internal cavity that is often filled with calcite, galena, chalcopyrite, etc.

The total thickness of the Nahorianska Suite in the gully reaches about 40 m. The analysis of the lithological composition of the Suite allows us to determine the conditions in which the rock was formed. Taking into account the signs of folds, oblique lamination, the presence of glauconite in sandstones of the Dzhurdzhivki Layers, it can be stated that it developed in conditions of shallow water marine basin.. By contrast, the Kaliuski Beds formed in conditions of deeper waters. This is indicated by the thin lamination of clay rocks and insignificant content of sand and aleurite fractions in them. It is quite possible that over the Kalusky period, the marine basin in Podilly had obstructed water exchange with the ocean and experienced hydrogen sulfide contamination (Stratyhrafiya, 1971).

The Cretaceous system in the Church Ravine is represented by sediments of the Cenomanian Stage. They are embedded on the significantly eroded surface of the Kaluski layers, forming stratigraphic non-uniformity with a break of about 500 million years . The base the Cenomanian Stage is composed of a layer (almost 1 m) of dark green glauconitic sand with pebbles of rounded phosphorites and Vendian sanstones. Deposits of secondary phosphorites , which were washed out from the Kaliuski layers and re-deposited on the bed of the Cenomanian sea , were confined to this layer.

Unlike Bila Hora, the Cenomanian Stage in this locality is represented not by flint facies, but by the carbonate facies, in which are Cretaceous limestones dominate. These rocks are characterized by white or light grey colour and are 80-90% composed of calcite; the rest is globular silica (5-8%), clayey substance (up to 5%), aleurite grains, etc. (Stratyhrafiya, 1971). In the layers of Cretaceous limestones there are numerous concretions of spotted, black and grey flints, and opoka-type silicites. Less commonly, there are flinted traces of digging animals, skeletal remains of foraminiferans, small spicules of sponges and other faunal remains. Limestones are easily malleable, which allowed the caves of the Liadova rock monastery to be carved here in medieval times.

The Cenomanian Stage terminates with a thick (up to 10 m) layer of various flints covered with white crust, consisting of a mixture of calcite and chalcedony. The intervals between the flints are filled with a limey substance. Chaotic accumulation of flints in the layer allows one to conclude that a partial pre-Sarmatian wash-out of limestones occurred, out of which only flints have remained.

The Neogene deposits are composed of the Lower Sarmatian rocks, which in the Church Ravine has a rather mottled lithological composition. The lower layers are mainly represented by alternation of clayey quartzitic sands and sandy clays, in which typical Sarmatian forms of molluscs, including *Ervilia podolica*, occur. In the upper part of the Lower Sarmatian substage, sandy ooliths and limestone with shells dominate. The latter are much more solid and

often form cornices. At the top of the gully, a washed-out area of the The Sarmatian layer can be seen, into which the delluvial Quaternary loams are washed . They have a brownish colour and are slightly reminiscent of loess. Perhaps the modern Podnistrovia loess-free area is a consequence of the erosion of loess layers. In the loams, there are large amounts of well-rounded pebbles, in which grey-brownish and red jaspers dominate. These rocks are alien to this area and there is an opinion (Vyrzhikovskiy, 1926.) that they are of Carpathian origin.

Hydrogeological features of Church Ravine are also interesting. In the territory of the Liadova Monastery there are two powerful springs which originate in the Cenomanian water-bearing horizon. The lower spring is called Anthonieve and is especially revered by the people for its healing properties. It has been determined that these properties are conditioned by the significant saturation of water by silicon and a specific cationic-anionic composition. According to the classification it is a natural table water of hydrocarbonate-sodium-calcium-magnesium composition. Its pP is 7.11, hardness - 6.7 mg-ekv / l, total mineralization - 0.4-0.8 g / l.

The area around the monastery has a significant geomorphological value and is very picturesque. From the height of Tserkovna Hora, one can see a magnificent view of the Dniester, its gigantic loop that envelops the shallow shore of Moldova. Then on the left and to the right up to the horizon, there can be seen the heights of Bessarabsky and Podilsky plateaus. From this place, one can clearly observe that both plateaus are really one integrated plateau which, as if accidentally, is cut by the valley of the Dniester. On the other hand, this landscape clearly demonstrates the results of the grandiose geological activity of the great river.

The left, Ukrainian, bank of the Dniester is steep and rocky. In its white limestones, black entrances to the Nahorianski karst caves are seen. Closer to the observer, the solid rocky shore is interrupted by the winding valley of the Liadova. In this place, a wide alluvial valley is located, deeply cut into the shore. The valley was formed by alluvia of the Liadova river. The steep slopes around the plain form a high rocky amphitheater with numerous steep gullies which are whitened by their limestone internal parts.

The scientific and scientific-educational value of this territory can be indicated at least by the fact that out of the 21 geological relics recorded in Vinnitsa Oblast (Korotenko, 1985), three of them are within a radius of 1-1.5 km from the monastery, in particular an outcrop of the Cenomanian deposits near the Liadova village, stratotype of the Nagoryany Suite and caves in Nahoriany village. It should be mentioned that old (from the 1870s) mining works for the extraction of concretionary phosphorites remain completely unexplored (Korinnyy, 2016). Adits are arranged along both slopes of the Liadova, and some of them, according to the locals, are 500 or more meters deep in the rocks.

Compared to other cave monasteries, the cultural-historical significance of the Liadova Monastery seems to be better explored, especially after the publication of a book V.V. Davydenko “Monastery” (Davydenko 2006). In this, without exaggeration, fundamental study, the author not only covered the historical assessment of the Liadova monastery, but also deeply analyzes the socio-political situation at a particular time which determined the fate of both the monastery itself and the fate of our people.

The relatively good state of knowledge about the Liadova monastery is evidently conditioned by its millennial history, which did not experienced long interruptions.

The territory where Liadova monastery is located has been used by man since Paleolithic times. This is evidenced by the numerous findings of stone tools near the mouth of the Liadova and the Nahoriansky caves. Perhaps, the cavemen occupied part of the Liadova caves (the other part has an artificial origin).

Other interesting and unique objects are the megalithic constructions with mysterious petroglyphs, located near the caves on the slopes of Nagorianski rocks. They astonished researchers in the XIX century, but since that time they have not been seriously studied . Similarly to megaliths in other countries, they probably belong to the Neolithic or Bronze Age.Their cultic purpose is quite obvious. According to the scattered findings of sculptures of pagan deities, there was also a pagan sanctuary on the top of the Tserkovna Hora (Davydenko, 2006) in pre-Christian times.

In the XI century, the Christian era of the development of the Liadova rocks began. According to the legend (Dymytriy, 1995), in 1013 Anthony of the Caves, the founder of the Orthodox monasticism in Rus, on his way back along the Dniester from Mount Athos, where he took his monastic vows, to Kiev, carved a cell in the maleable limestone; there he lived for some time and preaching Christianity among the Tivertsi. Over time, like-minded people joined him. This led to creation of the Liadova male monastery. There is also another version (Davydenko, 2006) according to which the Christian monastic caves in the Liadova rocks existed long before Anthony

arrived there and even before the emergence of the Kievan Rus itself. It is believed that the Dniester was a kind of bridgehead, from where Christianity tore its way to the east.

The first written mentions of the monastery date back to 1159. Since that time, all the vicissitudes of history have been reflected in the monastery's fate: feuds between princes, Mongol-Tatar rule, Lithuanian rule, Polish oppression, Tatar raids, Russian and Soviet times. More than once, the Liadova monastery became a kind of regional center of Cossack resistance and actively participated in peasant unrest . During the long period of its existence, the monastery has lived through periods of flourishing and decline. The prosperity was related to the well-known Liadova trade fairs held at the foot of the Tserkovna Hora, and where various goods from all over Podolia, Bessarabia and adjoining territories were brought. Certainly, the participants of the fair gave generous donations to the working churches. Since the late XVII century on the northern wall of the monastery, eminent guests of the monastery have left their autographs in different languages.

Since its foundation, the monastery has been repeatedly destroyed and devastated. Yes, obviously, the greatest damage was caused by an explosion set off by the Soviet authorities in 1938. However, after 10 years the ruins of the monastery became a state monument of architecture of the XI-XIX centuries. Now the remnains of the monastery are given to the Orthodox community willing to reconstruct it.

Even this rather superficial assessment of the geological and historical constituents of the described monuments demonstrates a number of regularities.

A place for a cave monastery was chosen on a mountain or in a high rock. This is due to several reasons. The first of them is probably a pagan tradition, according to which praying on high mountains brought you closer to the sky. That is why the idols, for example, to Perun or Sviativod, were placed on high hills. The proof of the borrowing of this custom is that in many cases Christian churches were placed on the site of ancient pagan temples.

Important for the emergence of cave monasteries was the early Christian tradition about the birth of Jesus Christ in Bethlehem Cave, which became the place of forgiveness of all Christians of the world. Therefore, Christian cave monasteries are found not only in Podillia, but also in the Crimea, near Jerusalem, in Greece, Italy, Bulgaria, Turkey (Cappadocia), Georgia, and elsewhere (Dymytriy, 1995). Another reason for the cave tradition was the persecution of the first Christians by adherents of different faiths, so they were forced to hide in inaccessible and protected places. Perhaps this is why the first Christian monasteries in Podillia and in Rus were cave monasteries. With the establishment of Christianity and with the development of the monastries, they became terrestrial cultic structures. For example, one can mention the Kyiv-Pechersk Lavra, the Holy Trinity Monastery near Satanov, etc.

Another aspect of the choice of site is lithological. Not just any high and inaccessible rock was chosen for a monastery, but a rock with natural (karst) hollows in it, which by additional processing could be made into monastic cells. If such were absent, suitable sites for foundation of a monastery were soft rocks, in which an artificial cave could be cut using primitive tools. That is, the rocks should have property of karsting (as in the case of the Neporotovo and Liadova monasteries), or be easily malleable (rocks of the Bakota and Liadova monasteries).

Hydrogeological conditions were also important for the construction of the monastery in particular, the accessability of sources of drinking water, which would not only assauge the thirst of the monks themselves, but also had an important "economic" role. After the monastery had been created, such springs became holy and were credited with healing properties. They contributed to the increase in the number of pilgrims, thanks to whose donations the monasteries existed.

However, no matter how important natural factors may seem to us, historical factors were determining. In the Middle Ages, the Dniester was an important trade route. At that time, the Dniester itself and its tributaries were deeper, providing unhindered passage to the merchant ships with grain, honey, craft goods, etc. Obviously, the first Christians appeared in mass along this route, as well as the cave monasteries, spreading the Christian faith.

Conclusions. The emergence of rock monasteries in the Middle Podniestrovie is conditioned by historical factors and favourable geological conditions for their establishment . A combination of religious (historical) and natural (geological) components are quite clearly seen on the example of Neporotovo, Bakota and Liadova rock monasteries. Such combination is conditioned by religious tradition and engineering-geological conditions of construction. The main factors which provided a combination of both components are: 1) high position of a monastery above the surrounding lowland; 2) provision of a minimum level of security for the monks; 3) presence of natural recesses or softness of rock; 4) availability of drinking water sources. Therefore, the locations of

the cave monasteries are often related to geological relics, forming integrated geohistorical attractions – geosites.

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The enrichment technology of slag from metallurgical processing of copper ore concentrate

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Abstract. The purpose of this research is the development of a technology for the enrichment of slag from metallurgical processing of copper ore concentrate based on the results of spectral, chemical, sieve and petrographic analysis. The results of spectral analysis indicate the copper content in all three samples of mineral raw materials at more than 1 %. The results of chemical analysis indicated a high copper content in the samples from 13.4 to 17.1%, as well as a high iron content from 9 to 18%. Analysis of the results of the sieve analysis showed that the largest amount of copper is contained in the size classes 0.063–0.05 mm at from 18.6 to 24.1 % and 0.04 mm at from 15.6 to 38 %. In accordance with the petrographic studies, the size of copper grains varies from 0.1–0.3 to 1–5 mm. The most common sizes of copper grains in the studied samples are 0.2-0.3 and 1-2 mm. Based on the results of spectral, chemical, sieve and petrographic analysis, a technology for the enrichment of copper-containing slags has been developed. Gravity wet enrichment technology with a capacity of 5 t/h with Cu recovery in the range of 80–95 % suggests the grinding of raw materials with a constant water supply up to 40 m^3/h from the sludge collector. The heavy fractions are fed to a magnetic separator and then to a classifier for the extraction of magnetic concentrate and slag, which after the separation of the fraction of 0.08-0.4 mm with the MVG screen can later be used as a raw material for the building industry. The light fractions after the concentration tables are fed to the classifier, on which the copper concentrate is released. The average density fractions are returned to the closed cycle for further grinding in a ball mill. However, such a wet enrichment scheme requires a continuous water supply and the sludge collector's presence, which cannot always be ensured. Therefore, the technology of slag dry enrichment with a particle size of 0–100 mm has also been developed. The central apparatus in the proposed enrichment technologies is the MVG vibrating screen, which is designed to separate bulk materials by particle size from 20 microns to several millimeters. Polyfrequency oscillations in the frequency range from several Hz to kHz are implemented on the screen, eliminating blockage of the sieve cells, destruction of the formed aggregates of stuck particles, ensuring their intensive movement in the layer and efficient passage of particles reaching the sieve surface through the cells. This type of vibration makes it possible to achieve much greater efficiency of separation and dehydration of materials than in traditional screens and to ensure continuous self-cleaning of the mesh, which contributes to the process of separation and dehydration. Due to the lack of tension, high durability of the working surface is ensured. Due to the transfer of minimum loads on the base, the screen is installed without arranging special foundations, including on the floors of buildings and structures. A standard-sized row of screens was developed with a screening surface area from 1 to 4 m^2 and a different number of tiers.

Key words: spectral, chemical, screening, petrographic analysis, enrichment technology, slag metallurgical redistribution of copper ore concentrate.

Технология обогащения шлака металлургического передела концентрата медной руды

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Анотація. Мета досліджень - розробка технології збагачення шлаку металургійного переділу концентрату мідної руди на основі результатів спектрального, хімічного, ситового і петрографічного аналізу. Проведено спектральний, хімічний, ситової і петрографічний аналіз мінеральної сировини. Результати спектрального аналізу вказують на вміст міді у всіх трьох зразках на рівні більше 1%. Результати хімічного аналізу вказали на високий вміст міді в зразках від 13,4 до 17,1%, а також на високий вміст заліза від 9 до 18%. Аналіз результатів ситового аналізу показав, що найбільша кількість міді міститься в класах крупності 0,063-0,05 мм від 18,6 до 24,1% і 0,04 від 15,6 до 38%. Відповідно до петрографічних досліджень, розмір зерен міді

коливається від 0,1-0,3 мм до 1-5 мм. Найбільш розповсюджені розміри зерен міді за дослідженими пробам - 0,2-0,3 мм і 1-2 мм. На підставі результатів спектрального, хімічного, ситового і петрографічного аналізу розроблена технологія збагачення мідьмістких шлаків. Технологія гравітаційного мокрого збагачення продуктивністю 5 т/годину з вилученням Cu в межах 80-95%. передбачає подрібнення вихідної сировини при постійній подачі води до 40 м^3/годину з шламонакопичувача. Важкі фракції надходять на магнітний сепаратор і далі на класифікатор для виділення магнітного концентрату і шлаку, який після виділення фракції 0,08-0,4 мм грохотом МВГ в подальшому може бути використаний в якості сировини для будівельної галузі. Легкі фракції після концентраційних столів надходять на класифікатор, на якому виділяється мідний концентрат. Середні по щільності фракції повертаються в замкнутий цикл для подальшого подрібнення в кульовому млині. Однак, така схема мокрого збагачення вимагає безперервної подачі води і наявності шламонакопичувачів, що не завжди може бути забезпечено. Тому, також розроблена технологія сухого збагачення шлаку з розміром частинок 0-100 мм. Центральним апаратом в запропонованих технологіях збагачення є вібраційний грохот МВГ, який призначений для поділу сипучих матеріалів по крупності частинок від 20 мікрон до декількох міліметрів. На ситі грохоту реалізуються полічастотні коливання в діапазоні частот від декількох Гц до кГц, при цьому виключається забивання осередків сита, забезпечується руйнування агрегатів, що утворилися з злиплих частинок, реалізується їх інтенсивне переміщення в шарі і ефективне проходження частинок, які досягли поверхні решета через осередки. Такий характер вібрації дозволяє домагатися значно більшої ефективності поділу і зневоднення матеріалів, ніж в традиційних грохотах і забезпечити постійне самоочищення сітки, що сприяє процесу поділу і зневоднення. Через відсутність натягу, забезпечується висока довговічність робочої поверхні. Через передачі мінімальних навантажень на підставу грохот встановлюється без облаштування спеціальних фундаментів, в тому числі на перекриттях будівель і споруд. Розроблено типорозмірний ряд грохотів з площею поверхні, що просіює від 1 до 4 м^2 і різним числом ярусів.

Ключові слова: спектральний, хімічний, ситової, петрографічний аналіз, технологія збагачення, шлак металургійної переробки концентрату мідної руди.

Introduction. Currently, the issues of improving the enrichment technologies of metallurgical wastes to increase the productivity and efficiency of extraction of useful components for their subsequent use are highly relevant (Cao, H. et al 2012, Chaabia, R. et al 2015, Lei, L. et al 2009, Mahmoudi, E. et al. 2018, Malanchuk, ZR, Malanchuk, E.Z. 2014, Rozendaal, A., Horn, R. 2013). When developing such technologies, it is important to take into account both the material composition of the raw materials (the content of an element and its compounds) and the features of the inclusions of useful components: their grain, shape, etc. For this, spectral, chemical, sieve and petrographic analysis of mineral raw materials are necessary.

The purpose of the research is the development of a technology for the enrichment of slag from metallurgical processing of copper ore concentrate based on the results of spectral, chemical, sieve and petrographic analysis.

Materials and research methods. The feedstock was slag from metallurgical processing of copper ore concentrate. For the analysis, several samples of slag from metallurgical processing of copper ore concentrate were taken (samples 567, 568, 569, 570).

The results of the spectral analysis are given in Table 1.

The analysis was performed using the "sprinkle method" on a STE-1 device with the ASI-10 annex. The results of the spectral analysis indicate the copper content in all three samples at more than 1 %. Among other elements with a relatively high content percentage, Ni, Zn, Co, Pb and Cd should be allocated. Os, Sb, Cd, U, Hf, Hg, Th, Ta, Au were not detected.

For a more accurate determination of the copper content, chemical analysis of samples was performed. The results of chemical analysis are given in Table 2. The results of chemical analysis indicated a high copper content in the samples from 13.4 to 17.1 %, as well as a high iron content from 9 to 18 %.

To determine the specific copper content by size class, a sieve analysis of the samples was carried out. The results of grain-size researches of samples of materials containing Cu are given in Table 3.

Analysis of the results showed that the greatest amount of copper is contained in the size classes of 0.063-0.05 mm from 18.6 to 24.1 % and of 0.04 mm from 15.6 to 38 %. The results of sieve analysis must be considered when drawing up the technological scheme of enrichment and the choice of the classifying means by size of copper-containing raw materials.

To determine the grain size, the shape of grains and their distribution over the samples, a petrographic

Table 1. Spectral analysis results

Sample №	The content of elements in % 10^{-3}																													
	Ba	Be	P	Cr	Pb	Sn	Ga	Ni	Y	Yb	Zn	Zr	Co	Ti	Cu	V	Ge	Mo	Li	La	Sr	Mn	Ti	W	Bi	Nb	Sc	Ce	Ag-6	As
567	<50	<0.1	70	200	500	150	0.2	200	-	-	700	5	5	30	»1%	3	<0.1	3	<1	2	<7	70	-	15	un.	0.1	-	-	150	-
568	<50	<0.1	70	150	700	100	0.3	150	-	-	≈1%	5	5	20	»1%	2	0.15	5	<1	2	<7	70	-	15	un.	0.1	-	-	150	-
569	<50	<0.1	50	200	≈1%	70	03	100	-	-	700	5	3	30	»1%	7	0.1	0,5	<1	2	<7	50	-	3	un.	0.1	-	-	150	-
Method sensitivity	50	0.1	50	0.1	0.1	0.1	0.1	0.1	1	0.1	1.5	5	0.5	1	0.1	0.3	0.05	0.05	1	2	7	1	0.1	0.5	un.	0.1	0.7	3	2	3

Table 2. Chemical analysis results

Item №	Sample №	Results are given in % for the dried substance at 105 °C						
		Cu	Ni	Zn	Co	Pb	Cd	Fe
1	567	13.4	0.17	0.67	00043	0.40	0.0002	18
2	568	18.5	0.12	1.37	0.0049	0.67	0.0001	15
3	569	17.1	0.09	0.63	0.0032	0.89	0.0005	9

Table 3. Sieve analysis results

Item №	Size class, mm	Mass, g	Content, %
Material № 1			
1	+0.2	39.2	8.5
2	0.2 – 0.16	21.3	4.6
3	0.16 – 0.1	40.3	8.7
4	0.1 – 0.09	10.5	2.3
5	0.09 – 0.071	39.7	8.6
6	0.071 – 0.063	17.3	3.7
7	0.063 – 0.05	111.6	24.1
8	0.05 – 0.04	7.0	1.5
9	-0.04	175.5	38.0
Total:		462.4	100
Material № 2			
1	+0.2	109.6	22.4
2	0.2 – 0.16	48.2	9.8
3	0.16 – 0.1	80.6	16.4
4	0.1 – 0.09	14.9	3.0
5	0.09 – 0.071	50.3	10.3
6	0.071 – 0.063	15.1	3.1
7	0.063 – 0.05	91.1	18.6
8	0.05 – 0.04	3.9	0.8
9	-0.04	76.4	15.6
Total:		490.1	100
Material № 3			
1	+0.2	101.1	20.7
2	0.2 – 0.16	39.9	8.2
3	0.16 – 0.1	65.1	13.3
4	0.1 – 0.09	11.6	2.4
5	0.09 – 0.071	46.6	9.6
6	0.071 – 0.063	14.2	29
7	0.063 – 0.05	106.7	21.9
8	0.05 – 0.04	6.9	1.4
9	-0.04	95.9	19.6
Total:		488.0	100

analysis was performed. The analysis was performed using a POLAM R-111 microscope. The results show the following.

Sample № 567 (Fig. 1) - the bottom layer of melting. Dense, chipped dark grey, chipped shell, a massive texture, surface with greenish and brownish scurfs of copper and iron oxides, the content of which in this sample: Cu - 13.4 %; Fe - 18 %.

The sample consists of colourless long prismatic narrow (0.05 mm) grains from 0.3 mm to 1.5-1.8 mm long and more, which are randomly intertwined, and in some areas are parallel or cross. They have a cleavage, low birefringence, direct extinction , some up to 3º. In the composition of the sample, these grains prevail - 65-70 %. Between them there is a dark opaque (isotropic) substance - 20–25 % and single short column-like grains with cleavage and direct extinction 0.09 mm long (pyroxene?). In this mass, there are voids of an isometric form ranging in size from 0.05-0.1 mm, some up to 0.2 mm, and also xenomorphic, isotropic grains with “needles” similar to goethite of dark brown (reddish) colour – 5 %. In addition, there are peculiar inclusions of red colour with a brownish tint of irregular square, trapezoidal shape with a size of 0.25-0.3 mm, similar to native copper. Some of them have jagged contours. Most of the copper formations are surrounded by an opaque dark earthy mass. The number of these inclusions is ~ 5-7% (in the polish field). Chemical analysis shows the weight percentage of native copper in this sample to be 13.4 %. Copper grains are distributed relatively evenly throughout the sample volume, which can be clearly seen on the sample № 567 cut.

An exemplar of this sample has distinctly manifested magnetic properties that indicate the possible presence of pyrrhotite, magnetite, cubanite or other magnetic minerals.

Sample № 568 (Fig. 2) is relatively dense and

heavy (up to 3-3.5 g/cm^3) slag of the third layer, in the upper right corner there are cuts of copper, ranging in size from 0.2 to 1.0 mm. The slag surface has a greenish scurf of copper oxides and a reddish scurf of Fe oxides, which suggests that the slag had remained in the dumps for a long period (for decades?). In general, the sample is of the same composition (with sample № 567), but the processes of replacement by an opaque dark mass of precisely colourless long prismatic grains are more intense. Relics of the latter are ~ 15-20 %. In transmitted light, dark matter has a lumpy shape, close to the isometric one. The size of the "lumps-balls" is 0.05 mm on average. On the periphery of these balls are scattered powder-like, dark gray fine particles with a metallic lustre, visible only in reflected light (chalcocite?, cuprite?). Optically their sizes cannot be determined. Opaque earthy substance is ~ 80-75 %. Single hair-like aggregates (sheaves) of a dark colour (0.01-0.03 mm) appear. In the upper right part of the sample cut, oval grains of copper are visible, ranging in size from 0.2 to 1.0 mm. The rest of the cut in reflected light shows smaller grains of native copper (0.2–0.3 mm), distributed relatively evenly in the sample mass. Probably, large-scale copper smelting is confined to the lower part of the melting layers.

Fig. 1. Sample 567

This sample also has magnetic properties, and the surface is covered with greenish and brownish scurf of copper and iron oxides. In this sample, according to the chemical analysis, copper is 18.5 % (the largest amount). Iron is 15 %, but its mineralogical composition cannot be determined after melting.

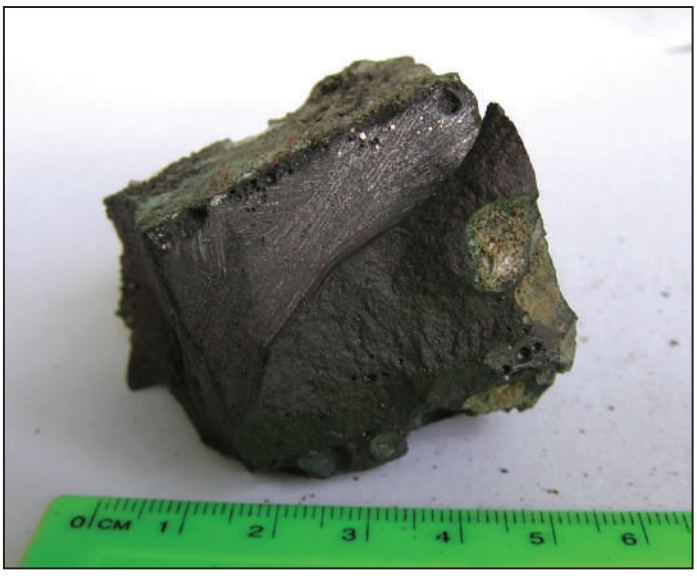

Fig. 2. Sample 568

Sample № 569 (Fig. 3) consists of a granular mass uneven in size, dark, brownish-black colour of cemented lumps with a diameter from 0.1 to 1.2 mm, in which there are: voids (from 0.1 to 0.55 mm), red

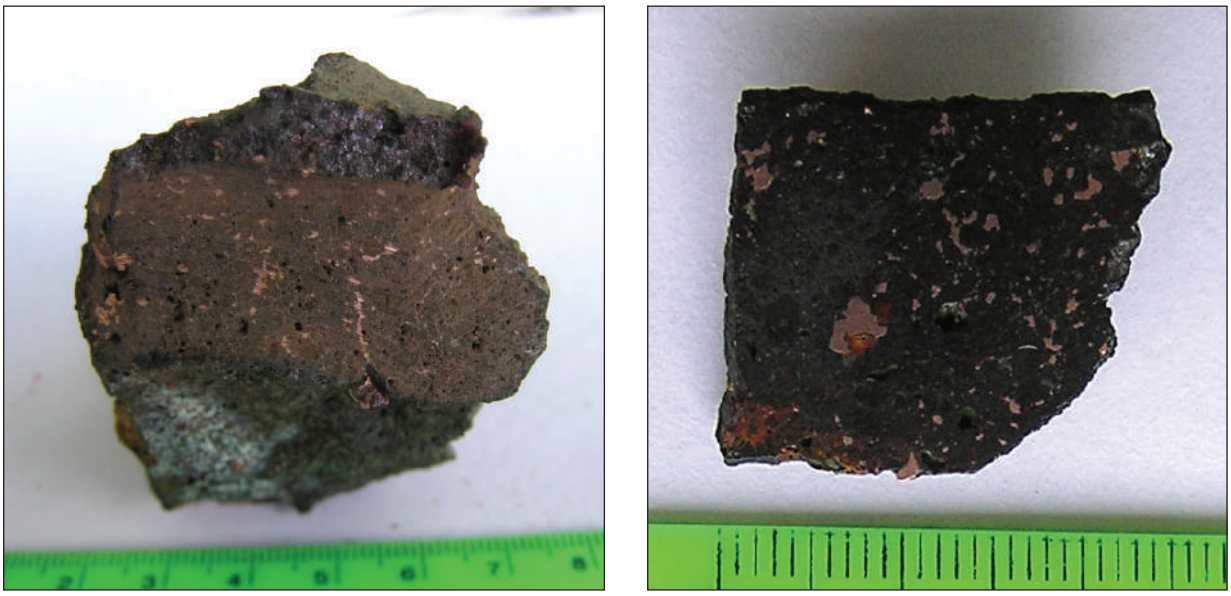

Fig. 3. Sample 569

isotropic inclusions (from 0.07 to 0.5 mm) of native copper, hair-like clusters and colourless clear grains (carbonates?) that surround the copper formations.

A dark shell is visible around individual copper formations, just as in a lumpy mass. Shell thickness is 0.02 mm. The copper content of ~ 15-17 % does not exclude the presence of copper formations in the dispersed state in a dark lumpy mass. In accordance with chemical analysis, in this sample native copper is 17.1 % , represented by relatively large grains. Grains ranging in size from 0.1 to 3-5 mm are visible on the cut of the sample. Large grains are more often represented by filamentous, dendritic forms, curved petals, less commonly isometric, spheroidal formations (probably this is copper that has fallen into cavities). Copper grains are evenly distributed in the sample mass.

There is no noticeable magnetism in this sample; probably there are few magnetic minerals. Iron in the sample is about 9 %.

Sample № 570 (Fig. 4) is a spongy, porous, relatively light (1.2-1.4 g/cm^3) slag of the upper (first) melting layer. This layer is characterized by a very weak magnetism, relatively low contents of Fe and Cu.

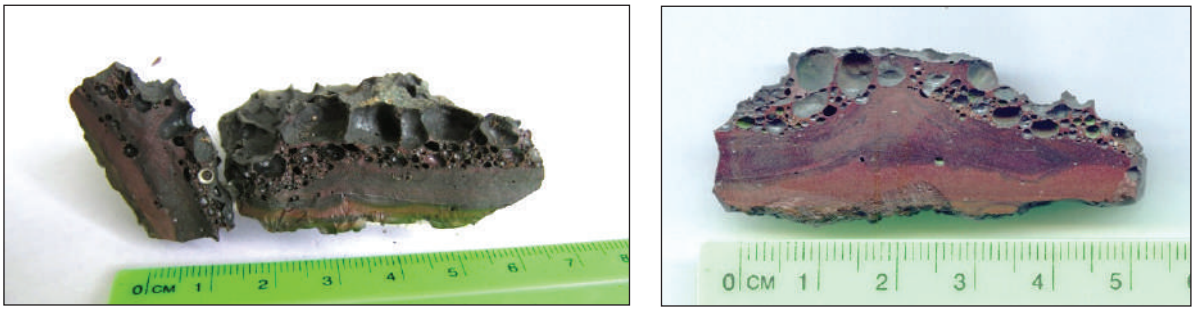

Fig. 4. Sample 570

On the basis of the conducted petrographic analysis, it can be concluded that the parent rocks with a certain content of ore minerals may have been ultrabasites and basic rocks. In the sample of slag № 567, areas of the primary structure are observed — non-metallic minerals fragmentarily create a structure similar to the "diabase" one. The second (№ 568) and the third (№ 569) samples demonstrate an increase in the intensity of secondary transformations in the slag composition.

The content of native copper in the slag according to chemical analysis ranges from 13.4 to 18.5 %. Iron content ranges from 9 to 18%. In accordance with petrographic studies, the size of copper grains ranges from 0.1–0.3 to 1–5 mm. Drip melts of copper up to 1-2 cm are identified on particular samples, but their number is insignificant. The most common sizes of copper grains for the studied samples are 0.2-0.3 and 1-2 mm. Large grains of 5 mm or more in size are relatively few and they are more likely to have dendritic or leafy forms. Ore minerals are likely: sulfides and oxides of copper, iron and zinc.

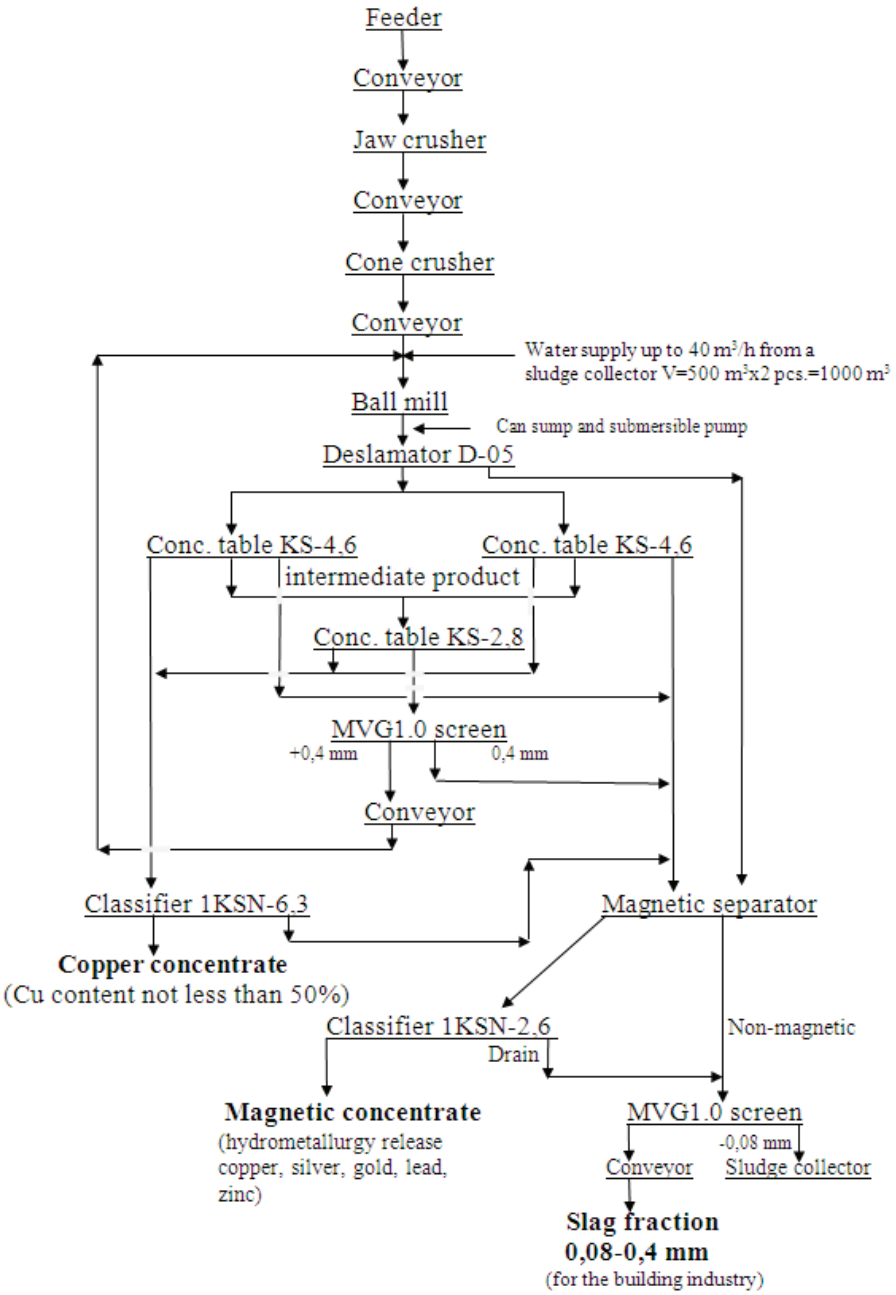

Fig. 5. Gravity enrichment scheme for copper-containing slags

Results and their analysis. Based on the results of spectral, chemical, sieve and petrographic analysis, a copper-containing slags enrichment technology has been developed.

The gravity enrichment scheme with a capacity of 5 t/h with Cu recovery in the range of 80–95 % is shown in Fig. 5. The nomenclature of the technology equipment is given in Table 4.

To ensure the operation of the wet enrichment technology, electrical cabinets, electrical equipment and lighting, grounding, slurry pipeline and drain chutes, trunk pipeline, adjustable water pipes with stop valves, electric pipes, cable and electrical wiring, abrasion resistant hose, metal constructions, ladders, crossings, platforms will also be required. The total electrical power of the equipment chain will be 104.1 kW.

The technology of wet gravity enrichment involves the grinding of raw materials sequentially in a jaw crusher, a cone crusher and a ball mill. Grinding in a ball mill occurs at a constant flow of water up to 40 m³/h from the sludge collector. After grinding, the raw material is fed into a slug catcher and further to the concentration tables, where the separation by density occurs. The heavy fractions are fed to a magnetic separator and then to a classifier for separating magnetic concentrate and slag, which, after separating a fraction of 0.08-0.4 mm at the MVG screen, can be used as a raw material for the building industry. The light fractions after the concentration

Table 4. The nomenclature of the equipment technology of wet enrichment of copper-containing slag with a capacity of 5-6 t/h

Item №	Type of equipment	Quantity, pcs	Electric power, kW
1	Feeder PK-10	1	3,0
2	Conveyor LK-12-650	6	13.2
3	Jaw crusher	1	11
4	Cone crusher	1	11
5	Ball mill MSC-1,6	1	22
6	Slug catcher D -05	1	-
7	Concentration table KS-4,6	2	4.4
8	Concentration table KS-2,8	1	1.5
9	Sand/submersible pump 63/23	1	11.0
10	Multi-frequency screen MVG1.0	2	2.4
11	Magnetic drum separator (60 m^3/h)	1	5.5
12	Spiral qualifier 1KSN-6,3	1	3.0
13	Spiral qualifier 1KSN-2,6	1	1.1
14	Sump	1	-
15	Centrifugal pump 60 m^3/h on a pontoon with a check valve and start system	1	15.0
	Total		104.1

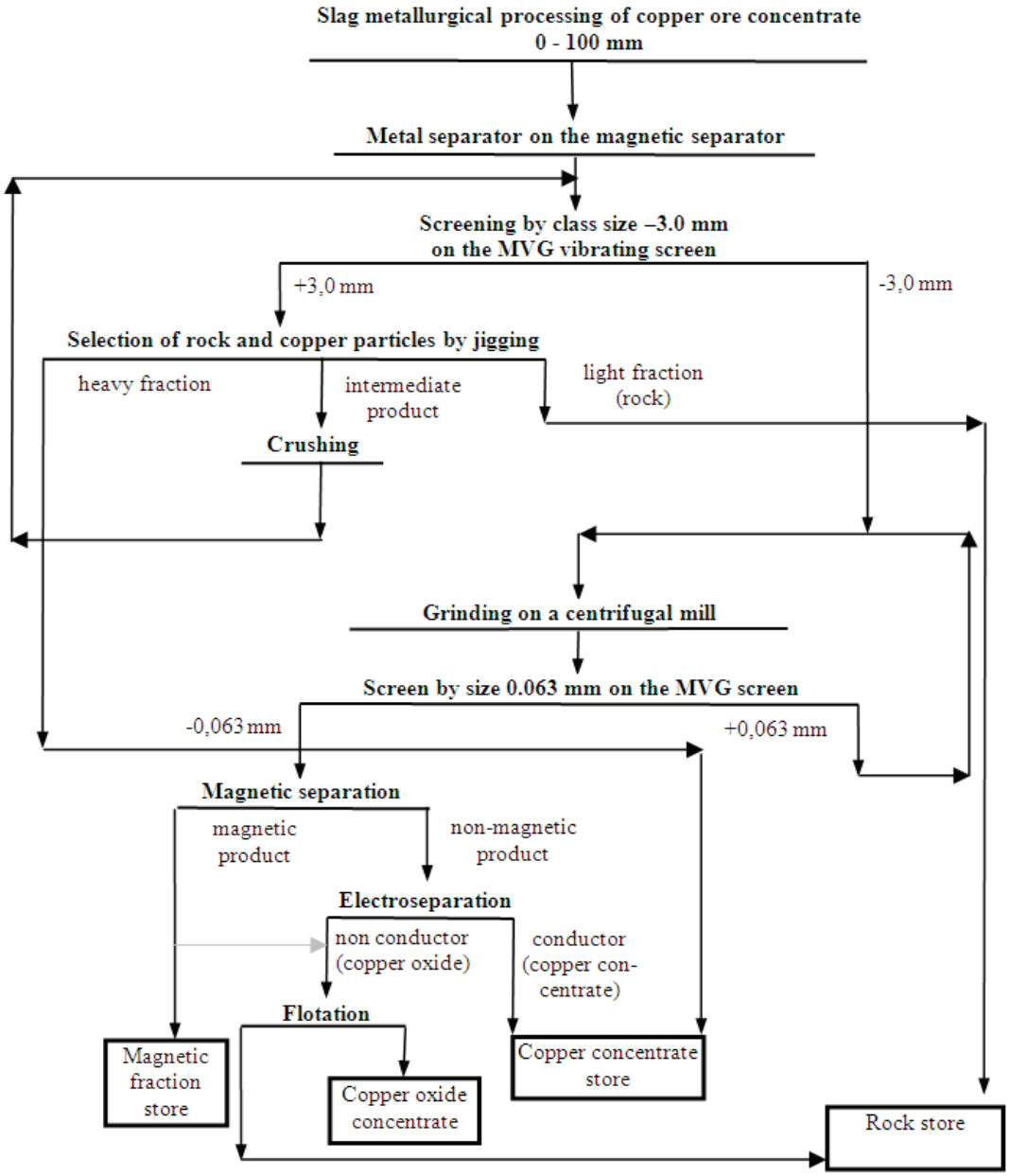

Fig. 6. Technological scheme for the enrichment of slag from metallurgical processing of copper ore concentrate with a particle size of 0-100 mm

tables are fed to the classifier, on which the copper concentrate is released. The average density fractions are returned to the closed cycle for further grinding in a ball mill.

However, such a wet enrichment scheme requires a continuous supply of water and the presence of sludge tanks, which cannot always be ensured.

The technological scheme of dry enrichment of slag with a particle size of 0–100 mm is shown in Fig. 6. Slag metallurgical concentrate of copper ore is fed to the magnetic separator, which provides for the separation of pieces of metal found in the raw material. Next, the concentrate is fed to the MVG vibrating multi-frequency screen for classification by size 3 mm. The –3 mm fraction is fed to grinding in a centrifugal mill. Fraction +3 mm - enters the jigging machine. After jigging, the light fraction (rock) enters the rock store, the heavy fraction (copper) to the copper concentrate store, and the intermediate product goes to crushing, and then is fed back to the MVG screen for classification by 3 mm. After grinding in a centrifugal mill, screening of 0.063 mm on the MVG multi-frequency screen takes place. The fraction +0.063 mm in a closed cycle is fed back to grinding, and the fraction -0.063 mm enters the magnetic separator. The magnetic product enters the store of the magnetic fraction for the subsequent extraction of iron, the non-magnetic product enters the electric separator, in which copper concentrate is released, which then enters the store, and copper oxide, supplied to the flotation, to separate the copper oxide itself from the rock.

The central apparatus in the proposed enrichment technologies is the MVG vibrating screen, developed at the Institute of Geotechnical Mechanics named after M.S. Polyakov NAS of Ukraine, which is designed to separate bulk materials by particle size from 20 microns to several millimeters (Shevchenko, G.A. et al 2016). Screening or separation of solid particles from slurries or suspensions and their dehydration at the MVG screen is carried out on woven meshes or rubber sieves performing polyfrequency vibrational oscillations.

Polyfrequency oscillations are implemented on the screen sieve in the frequency range from several Hz to kHz, thus blockage of the sieve cells is eliminated, destruction of the formed aggregates of stuck particles is ensured, their intensive movement in the layer and effective passage of the particles reaching the sieve surface through the cells is realized. This type of vibration makes it possible to achieve significantly greater efficiency of separation and dehydration of materials than in traditional screens and to ensure continuous self-cleaning of the mesh, which promotes to the process of separation and dehydration. Due to the lack of tension, high durability of the working surface is ensured. Due to the transfer of minimum loads on the base, the screen is installed without arranging special foundations, including on the floors of buildings and structures.

Multi-frequency screens can operate at high temperatures, in corrosive environments, in the water environment, in the mining, building, chemical, food, pharmaceutical industries, as well as in powder, ferrous and non-ferrous metallurgy to separate and dehydrate any bulk materials, purify polluted water, etc. A standard-sized row of screens was developed with an area of screening from 1 to 4 m^2 and a different number of tiers. The technical characteristics of the MVG screen with a screening area of 2 m^2 are given in Table 5.

Conclusions.

1. When developing technologies for enrichment of metallurgical production wastes, it is important to

Table 5. Technical characteristics of the MVG2.0 screen

Name of parameters, units of measurement	Value
Frequency of forced oscillations of the box, Hz	25
Number of motor vibrators, type IV-25-25	2
Motor vibrator engine power, kW	2.3
Separation size, mm	0.02–20
Conventional dimensions of the screening surface: - width, mm - length, mm	 1000 2600
Effective separation area, m^2	2.6
Angle of sieve surface, degree	0-10
Overall dimensions of the screen, mm - length - width - height at angle of sieve surface 0^0	 3810 1636 1607
Screen weight (without frame), kg	2800

take into account both the material composition of the raw material (the content of elements and their compounds) and the features of the inclusions of useful components: their grain size, shape, etc. This requires spectral, chemical, sieve and petrographic analysis of mineral raw materials.

2. The results of spectral analysis indicate the copper content in all three samples at a level of more than 1 %. The results of chemical analysis indicated a high copper content in the samples from 13.4 to 17.1 %, as well as a high iron content from 9 to 18 %. Analysis of the results of the sieve analysis showed that the largest amount of copper is contained in the size classes of 0.063–0.05 mm from 18.6 to 24.1 % and of 0.04 mm from 15.6 to 38 %. The results of spectral, chemical and sieve analysis must be considered when drawing up the technological scheme of enrichment and the choice of means of classifying copper-containing raw materials by size.

3. According to petrographic studies, the size of copper grains varies from 0.1–0.3 to 1–5 mm. Drip melts of copper up to 1-2 cm are determined on particular samples, but their number is insignificant. The most common sizes of copper grains for the studied samples are 0.2-0.3 and 1-2 mm. Large grains of 5 mm or more in size are relatively few and they are more likely to have dendritic or leafy forms.

4. Based on the results of spectral, chemical, sieve and petrographic analysis, a technology for the enrichment of copper-containing slags was developed: gravity wet enrichment with a capacity of 5 t/h with Cu extraction within 80–95 % and a dry enrichment technology of slag with a particle size of 0–100 mm.

5. The central apparatus in the proposed enrichment technologies is the MVG vibrating screen, which is designed to separate bulk materials by particle size from 20 microns to several millimeters. Polyfrequency oscillations are implemented on the sieve screen in the frequency range from several Hz to kHz, thus blockage of the sieve cells is eliminated, destruction of the formed aggregates of stuck particles is ensured, their intensive movement in the layer and effective passage of the particles reaching the sieve surface through the cells is realized. Such a nature of vibration allows a significantly greater efficiency of separation and dehydration of materials to be achieved than in traditional screens and constant self-cleaning of the mesh , which promotes the process of separation and dehydration. Due to the lack of tension, high durability of the working surface is ensured. Due to the transfer of minimum loads on the base, the screen is installed without arranging special foundations, including on the floors of buildings and structures. A standard-sized row of screens was developed with a screening surface area from 1 to 4 m^2 and a different number of tiers.

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Human geography in Ukraine: problems of development and priority research directions

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Abstract. The problems of development of scientific schools of human geography in Ukraine are determined. It is shown that contemporary human geography in Ukraine is a methodologically formed science with its own theoretical and methodological apparatus, which under the current conditions should be aimed at solving the applied problems regarding the improvement of the socio- territorial organization in Ukraine.The article analyses the different functional aspects of development of human geography in Ukraine. Among the main problems that hinder the development of scientific schools, and therefore the science in general, are the following: individualized activity of scientific schools without specific purpose, partial realization of their contribution to all-school social geography, and contribution to the world of science; the problem of definition , which is associated with the use of simultaneous usage of different terms for the science ;«economic and social geography», «socio-economic geography», «social geography»; the problem of social differentiation, geography and lack of a pivotal system of logically completed laws of science that could integrate different paradigms and research areas; lack of implementation of applied science functions and etc. Considerable attention is paid to the prospects of comprehension of human geography related to improvement of the theoretical basis in accordance with the realities of the beginning of XXI century, emphasis is placed on applied aspects of science and avoidance of pointless abstraction.The strategic goal of socio-geographical science is the determination of economic, demographic, social, political and environmental capacities of the geographic shell, justification of rational parameters of regional and global nature management, identification of the main trends of technological, sectoral and territorial development of the economy of Ukraine and its regions.It is proved that the main tasks of the science are also studies of the quality of life of the population; improvement of the structure of production and its transfer to an innovative level; definition and achievement of the optimal social, functional-branch and territorial structure of the economy; optimizing the structure of economic, social, political and other ties. At the regional and local levels, priorities include the problems of nature use and nature conservation, the development of depressed regions, the justification and implementation of regional economic, social, demographic and environmental policies. The key to solving these problems from the methodological point of view is the substantiation of the general theory of regional studies taking into account the diversity of the territorial organization of society.

Keywords:human geography, Ukraine, territorial organization of society, problems of science development, scientific directions, prospects of development of the science.

Суспільна географія в Україні: проблеми розвитку та пріоритетні напрями досліджень

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Анотація. Визначено проблеми розвитку наукових шкіл суспільної географії в Україні. Показано, що сучасна суспільна географія в Україні – це методологічно сформована наука із власним теоретичним і методичним апаратом, який у найтеперішніх умовах має бути спрямований на розв'язання прикладних завдань щодо вдосконалення територіальної організації суспільства в Україні. проаналізовано різні функціональні аспекти розвитку суспільної географії в Україні. Серед основних проблем, що перешкоджають розвитку науки є: індивідуалізована діяльність наукових шкіл без цільового призначення часткової реалізації її внеску в світову суспільну географію; проблема ідентичності, пов'язана з одночасним використанням назви «економічна і соціальна географія», «соціально-економічна географія», «суспільна географія»; проблеми диференціації географії та відсутності системи завершених законів науки, які могли б інтегрувати різні парадигми та напрямки досліджень; відсутність реалізації прикладних функцій науки тощо. Вирізнені проблеми розвитку суспільної географії: ігнорування самим суспільством результатів досліджень суспільно-географічної науки; розпорошення суспільно-географічних студій за новими напрямами досліджень; проблема самоідентифікації та диференціації науки; нереалізованість її прикладної функції тощо. Стратегічною

метою суспільно-географічної науки окреслено визначення економічної, демографічної, соціальної, політичної та екологічної ємності географічної оболонки, обґрунтування раціональних параметрів регіонального і глобального природокористування, виявлення основних тенденцій технологічного, галузевого й територіального розвитку господарства України і її регіонів. Доведено, що головними завданнями науки також є дослідження проблем якості життя населення; удосконалення структури виробництва та переведення його на інноваційний рівень; визначення та досягнення оптимальної соціальної, функціонально-галузевої й територіальної структури господарства; оптимізації структури економічних, соціальних, політичних та інших зв'язків. На регіональному й локальному рівнях – проблеми природокористування й охорони природи, розвитку депресивних регіонів, обґрунтування й реалізація регіональної економічної, соціальної, демографічної та екологічної політики. Запорукою розв'язання цих проблем з методологічного погляду є обґрунтування загальної теорії регіонознавства з урахуванням різноманіття територіальної організації суспільства.

Ключові слова: суспільна географія, Україна, територіальна організація суспільства, проблеми розвитку науки, наукові напрями, перспективи розвитку науки.

Introduction. The priority directions of fundamental scientific research on the most important problems of the development of scientific and technical, socio-economic, socio-political, human potential for ensuring the competitiveness of Ukraine in the light of sustainable development are identified at the legislative level. The problems of rational nature management today are successfully solved by the scientists specializing in the field of social geography. At the same time, it is necessary to outline the problems of development of human geography in Ukraine and to identify the priority directions of its further research in order to increase the status of human geography in Ukrainian society, primarily due to the effectiveness of research.

Modern human geography in Ukraine, according to K. Mezentsev (K. Mezentsev, 2010), «is at a crossroads», and the choice of the further path of the science's development depends on the essential awareness of its practitioners. One of the possible directions will involve conservatism of theory and methodology, self-satisfaction at achievements made, and the other will promote innovation and scientific research, one of them is oriented to the depth of the industrial society, the other towards the information society, one of them will lead to self-isolation, the other will ensure integration into world social geography.

During recent years of the XX – in the beginning of XXI century a number of works on methodology and theory of geography were published, articles that revealed problems and the development prospects of human geography in Ukraine, analysis of the state and strategy of the science's development, awareness of the mission and trends of human geography in the context of the latest challenges and demands of society,. The search for a place, role and the development prospects of the science was a key theme of the Ukrainian Geographical Society's congresses («Ukraine and Global Processes: Geographic Dimension», Lutsk, 2000; «Ukraine: Geographical Problems of Sustainable Development», Chernivtsi, 2004;«Geography in the Information Society», Kyiv, 2008; «Ukraine: Geography of Goals and Opportunities», Kyiv, 2013; «Ukrainian Geography: Modern Challenges», Vinnytsia, 2016). Among these works, it is especially worthwhile to highlight the research by M. Pistun «The Tasks of Human Geography in the Context of the Problems of Ukraine's Regional Development» (2003), «On New Development Directions of Socio-Geographical Research in Ukraine» (2005), K. Nemets «Human Geography: Problems and New Horizons» (2006), M. Bahrov «The Paradox of Unclaimed Geography and Its Development Trends» (2006), «The New Paradigm of Geography in the Information World»(2008),Y. Oliinyk «Tasks of Economic and Social Geography in the Information Society» (2008), L. Rudenko «The Problem of the Formation and Use of Spatial Data and the Problem of Geography» (2008), O. Shablii «The Imperative of Ukrainocentrism in National Geographic Science» (2008), K. Mezentsev «Problems and Prospects of Ukrainian Human Geography of the XXI Century» (2008),Y. Oliinyk and A. Stepanenko «The Development Strategy of Economic and Social Geography» (2009), E. Maruniak «Modern European Geography: Directions of Development» (2010), M. Bahrov, L. Rudenko and I. Chervaniov «New» Geography in Ukrainian Realities: Mission and Trends»(2012), O. Topchiiev, V. Nudelman and L. Rudenko «New Challenges and Inquiries of Geography (Ukrainian Aspect)»(2011), L. Nemets «Modern Social Geography: Analysis of the Situation, Problems and Prospects» (2012), M. Bahrov, L. Rudenko, I. Chervaniov «Progress of New Geography» – Essence and Purposes» (2012), P. Masliak «Public Geography: A Scientific Paradigm Shift in the XXIst Century»(2013), M. Dnistriansky «On the Need for a New Look at the Subject Human Geography» (2016), O. Topchiiev «Geography Subject Area and Its Modern Methodological Transformations» (2016) and others.

The basic generalizations for the future development of human geography in Ukraine are presented in the studies of L. Rudenko and M. Bahrov. They determine its transition to a qualitatively new stage of information geography, which studies the distribution of new knowledge and information, as well as the

formation, storage, processing and interpretation of specific geospatial-time coordinates using GIS technologies.The researchers identified key aspects of the current state of science in Ukraine and outlined the prospects of its development (Bahrov, 2005; Rudenko, 2006): geography has its own field of research that is not overlapped by any other science; geographic studies integrate new knowledge and information about space due to the high significance of the concepts of location, goal and development resources; Geography in Ukraine develops scientific concepts and ways of their implementation, striving to acquire the status of economic «pole of growth», in order to become, together with it, a «new» geography in the forefront of sciences that provide sustainable development.

O. Topchiev (Topchiev,2012), analyzing public requests for geographic science and the challenges that cause the formation of new approaches, concepts and trends in its theory and methodology, states that some of them have become recognized and spread, have become the latest paradigms of modern geography (geo-information, geo-planet paradigms). The scientist emphasizes that geographers should more actively develop a general-scientific intentional paradigm, which provides a new methodological understanding of the key problem for geography – the problem of interaction between society and nature.

Covering the tendencies of development of economic and social geography, the evolution of the subject of its study, the discipline's objectives in the context of the globalization of world-system connections, Y. Oliinyk (Oliinyk, 2009) is exploring the strategic directions of the development of fundamental research in economic and social geography; this entails determining the strategic directions of the science's formation of a unified planetary system, in which, according to the scientists, a significant role should belong to economic and social geography, intended to create the basis for the development and functioning of humanity in qualitatively new conditions.

O. Shablii justifies the principles and directions of the development of human geography in a rather interesting way, namely through the imperative of Ukrainocentrism as a means of intensifying the development of the science, which involves focusing the study of Ukraine as a natural-, demo-, social-, economic-, and politico-geographical isolation in the context of different levels of geospatial organization of the earth's nature and human civilization. The imperative of Ukrainocentrism also requires the removal of the semantic units of Soviet ideology's (Shablii, 2008).

According to K. Mezentsev, the challenges of modern human geography are related to the change in the methodology of socio-geographical research, which is determined by the analysis of spatial aspects of various transformational processes, the evolution of economic, socio-cultural, political activity of the population; justification of the prospects of regional development in view of the new factors; studying the processes of social polarization of the population, regional social security, spatial distribution of social problems and threats; combining quantitative and qualitative methods of research (traditional methods of spatial analysis, GIS analysis, geographic and mathematical modeling, on the one hand, and methods aimed at determining perceptual characteristics of regions, identifying regional stereotypes, regional self-identification of the population, on the other), using new methods of research (nonlinear modeling, neural networks, fractal geometry, fuzzy set theory, etc.).

In 2011, the Institute of Geography of the National Academy of Sciences of Ukraine held a scientific seminar «Geographical science in the new socio-economic conditions of development of Ukraine» , which identified the conceptual problems of functioning socio-geographical science in Ukraine. It is no coincidence that the XII Congress of the Ukrainian Geographical Society (2016) took place under the slogan «Ukrainian Geography: Modern Challenges», it paid great attention to the contemporary tasks of the development of socio-geographical science. A detailed analysis of the reports on the problems of the science which were made at the congress was carried out in the article by Y. Oliinyk (Oliinyk, 2016). The author acquainted readers with the views of national scholars on the problems and prospects of the development of social geography.

The most interesting, in our opinion, are the researches by L. Rudenko, O. Topchiiev, P. Masliak, V. Oleschenko, S. Bortnik, A. Gudzevych and M. Dnistrianskyi. L. Rudenko stressed that geographic research should focus on practical activities in the regions (regional development strategies, various types of territorial planning, etc.) regarding the mechanisms of implementing the principles of balanced development; intensify the work of the scientific geographic schools for the formation of innovation-oriented economy; take part in a strategic environmental analysis. O. Topchiev proposed in the geographical sciences along with two traditional branches (natural and social) to form a new direction – the development of theoretical and methodological principles of functioning of the Earth's landscape as a holistic and complex socio-economic natural system (Topchiiev, 2016).P. Masliak defined the priority task of modern geography – modeling the territory in accordance with scientific geographical representations about its harmonious and effective development; this direction, in the opinion of the scientist, will ensure

the unity of geographical science (Masliak, 2016). V. Oleshchenko proposed to introduce a new specialty «theory of geography» for those studying towards scientific degrees (Oleshchenko, 2016). In our opinion, the specialty «theory and history of geography» would be more optimal, like a similar scientific specialty in other fields of knowledge. S. Bortnik, together with other scientists, determined the objective of geography in Ukraine in the development of new scientific and applied areas based on the use of world experience of spatial development, geo-planning, landscape development of the territory and modeling in the system of multi-level management. A. Gudzevych analyzed the space-time paradigm of science and proposed to develop national geography as a science of a single planetary system, paying particular attention to geo-space and geo-environment (Gudzevich, 2016). M. Dnistrianskyi raised the issue of the need for a new substantiation of the subject of human geography as a humanitarian geographic science on geospatial development, placement, vital activity and interaction of human communities and the formation under their influence of cultural landscapes. According to the scientist, the combination of human communities as special territorial-organized social entities and cultural landscapes of the Earth's surface provides the substantive filling of the socio-geographical world and creates the framework of geographical space in general. According to this approach, M. Dnistrianskyi proposed that human geography be considered not as a set of social spatial forms of social objects, but as a humanitarian geography, in the epicentre of which the geographic world of human societies is located (Dnistrianskyi, 2016).

Some of the reports were devoted to the methodological problems of applied socio-geographical research and new directions of development of the science, namely: geography of tourism (G. Balabanov, O. Liubitseva, M. Malska, L. Zelenska, O. Kolotukha), geography of the quality of life of the population (I. Hukalova), military geography (Y. Ivakh), methods of multidimensional analysis (K. Niemets, L. Niemets, K. Sehida), geopolitical paradigm and political geography (Y. Oliinyk, A. Stepanenko, B. Yatsenko), territorial planning (H. Pidhrushnyi) and others.

The purpose of the paper. The generalizing idea in the works of most modern Ukrainian scholars is the recognition and justification of human geography as a methodologically formed science with its own theoretical and methodical apparatus, which in the present conditions must first of all be directed at solving applied problems concerning the improvement of the territorial organization of society in Ukraine. At the same time, the theoretical foundations of the science, first of all, through the introduction of new approaches, concepts, etc, need a certain development as well.The purpose of this paper is to determine the problems of the development of human geography in Ukraine and to formulate promising directions for its research.

Results and discussion. The factors determining the problems of contemporary human geography are the ignoring of the results of research of spatial science by society itself («consumer society»), as well as the extension of socio-geographical research into new areas, especially those that are formed on the frontier with other sciences (regional economics, regional demography, regional sociology, regional policy, etc.). Using the subject of human geography and applied aspects which are contiguous with social science disciplines, artificial creation of new scientific fields, as well as sciences (regional economics, regional cultural studies, etc.) can lead to the transformation of fundamental science into the method of studying these sciences.Public geography, which is part of the system of geographical sciences, is, of course, a component of the wider system of Earth Sciences, but its successful development is impossible without close links with social sciences. At the same time, in recent years, the intensification of such connections has been observed.Modern connections of human geography with economics , sociology, political science, demographics, computer science and management lead to strengthening of the applied direction in geography. Within the framework of the implementation of the applied science function, the participation in evaluative, forecasting works and territorial planning, programming and estimating becomes important. It is by this very point that human geography as the only science based on spatial methodology should be opposed to the directions of regional studies of social sciences.

While highly appreciating the scientific achievements of human geography in Ukraine, it should be noted that in today's conditions there is a sharp decline in interest in solving its theoretical problems, developing new concepts, modernizing the formed theories. In this case, from the side of social geography, the practice of fragmentary incursions into the field of the adjacent social disciplines is expanding. Modern human geography in Ukraine has to win its monopoly on spatial research, thus restoring its position in the system of sciences.

The analysis of the problems of human geography development in Ukraine gives grounds for determining the problems of its functioning. The further development of human geography in Ukraine depends on the operational actions of modern scientists. Among the main problems which restrain the development of

social geography, one should note the following.

1. Individualization of the activities of scientific schools without formulating the concrete goal of realizing its contribution to the all-Ukrainian school of social geography, and through the latter, to world science. The lack of a tradition of coordination and consolidation of socio-geographical schools has resulted in the dissociation of the socio-geographical community and the inconsistency of scientific research. Despite having in its arsenal extremely important scientific achievements, as well as practical results of research on society's territorial organization, public geography in Ukraine remains almost non-integrated into world science, and dialogue with other national schools is practically absent. Scientific knowledge is known to be universal, but national specificity in socio-geographical research should be manifested even when it comes to fundamental theoretical problems.In such a situation, within each of the directions of human geography there are points of intersection with various adjacent social sciences, and intersection areas with the scientific schools of these social sciences. As a result, there is a further differentiation of socio-geographical science. That is why the main direction of the development of science should be the synthesis of the achievements of a modern school of human geography with its fundamental development of an integrated approach to studying the territory, on the one hand, and the modern theory of synergetics of large systems in relation to spatial-dynamic structures, on the other. We see another way of overcoming this problem in the coordination of the subjects of research under the auspices of the Institute of Geography of the National Academy of Sciences.

2. Over the past decades, the problem of self-identification of human geography has increased. Until 2015, it was defined only by the incongruity between the name of the science in the scientific environment of Ukrainian geographers as «social geography» and the official name of the vast majority of university departments and the specialty of the graduates of scientific degrees as «economic and social geography». The introduction of a new list of academic fields and specialties in 2015, according to which higher education graduates are trained, means that social (economic and social) geography is dissolved in the science system under the name«Earth Sciences».Officially, the name «social geography» has long been used only in the name of one department of the Institute of Geography of the National Academy of Sciences (the Department of Social and Geographical Research). Until recently, Ukraine's only department of «social geography» existed at the Lesya Ukrainka Eastern European National University. Simultaneously among scientists of Ukraine different names are used («economic geography», «socio-economic geography», «human geography»), and when writing scientific works, in particular theses, the preference is given to the name «human geography».

3. The process of internal differentiation of human geography in Ukraine is still far from its completion, since not all elements that form the territorial organization of society have become objects of research. The process of internal integration of human geography influences its diversification as well. The processes of differentiation and integration of human geography directly relate to the development of its theory, on the one hand, the formation of the social sciences' branch theory, and on the other – the development of the general theory of science on the whole. Modern human geography is characterized by the absence of a logically complete system of scientific laws, the predominance in the science of intra-academic principles and forms of theorization associated with the gradual generalization of empirical material in certain areas, which prevents it from reaching a higher level of abstraction. We face the paradox in which the branch directions (economic geography, geography of population and resettlement, political geography, etc.) today have a better proved, drawn up and represented methodology than the science which unifies them – social geography. Human geography in the conditions of its scientific potential and experience needs to solve this problem and, consequently, such a structured system of scientific laws has to appeal to those worldview and civilizational circumstances of scientific development which exist outside the boundaries of social geography. Taking into account the above conditions will facilitate the transition of human geography to a new scientific activity paradigm as a science of geospatial self-organization of society, its types, forms and relations.That very activity paradigm of geospatial relations, in our opinion, via their specific relations system (geo-economic, geo-social, geopolitical, geo-spiritual) will provide further assured development (without any trespassing on adjacent social sciences) of the four fundamental components of social geography – economic, social, political geography and cultural geography. For their part, today, they already have the established indisputable specific areas of cognition (subjects of research) and can contribute to the transformation of their own theoretical concepts as components of a wider scientific social and geographical world picture.

4. Changes in specific objects and subjects of modern human geography are generated by the informatization processes; they differ from the objects of industrial society research, production processes, etc.

First of all, they deal with the information economy, information and communication infrastructure, network forms of economic activity organization, the information society as a whole and the phenomena it results in . In the process of Ukraine's transition to the information society, national human geography will not remain a landmark science of industrial society and will not go back to the past.The changes and challenges of the information society concern the foundations of social geography: the subject-object area is expanding (comparatively new directions are developing – quality of life geography, geography of social problems, perceptual, gender, electoral, sacral geography, etc., new methodological approaches are used (behavioural, synergetic); the methodological apparatus of social and geographical research is being improved (Mezentsev, 2010).

Consequently, in the absence of a core system of logically complete scientific laws, we face infringement of adjacent social sciences on the subject field of social geography, via their regional directions, as well as the tendencies of departure from actual social and geographical research as social geographers become embroiled in the aspects of adjacent social sciences and, accordingly, spatial analysis of these aspects. All this can lead to the decrease of positive trends in the development of socio-geographical science.The way out of the situation is seen in the consolidation of scientific-educational research and school-groups on the activation of theoretical and methodological developments. Promising in this regard are the geospatial-time theory, the theory of geospatial organization of society and the theory of territorial systems that will provide the theoretical substantiation of geospatial self-organization of society as an appropriate complex (system) that has regional (geospatial) differences and needs management. In such conditions, the results of the science will become popular in society, and therefore the status of human geography will increase, it will become more popular.

5. From the above follows another problem of the development of scientific schools in human geography– the failure of its application function. According to K. Mezentsev, a significant part of socio-geographical research in Ukraine is devoted to the study of traditional objects by traditional methods. Many socio-geographical works are based on outdated methodology and are characterized by scientific formalism, while other studies reveal a «theory for theory», where new terminological constructs, alternate complexes and systems do not result in any useful conclusions.Unsuccessful, according to the scientist, are the attempts at artificial «dragging» of the classical geography of production methodology (economic geography) into modern service, information and communication and network objects of research. Therefore, such challenges are connected with the non-recognition of the practical value of socio-geographical research. In view of the various reasons, the implementation of the science constructive potential is limited enough; there are no real government orders for the scientific development of regional forecasts, programmes, schemes, etc.

The theories we talked about above, taking into account the developments of human geography in Ukraine and the new ideas of the development of world science, should become the methodological basis of social geography, and most importantly –give it the opportunity to realize its constructive function in improving the processes of human life. The processes of complex and system formation are manifested in the territorial self-organization of all spheres of human activity, the emergence and expansion of socio-economic relationships and relations, the transformation of the natural environment, the consolidation of territorial communities of people.Territorial centres are formed, all spheres of human life there are interconnected and they are included in the processes of social functioning, development and reproduction. The territorial self-organization of society has the properties of differentiation and discretization, which manifest themselves in the form of the administrative-territorial structure and the system of regions of different taxonomic rank. Regional units of any level of the hierarchy are self-organized territorial systems that are specifically implemented in the socio-geographical space and historical time. It is precisely in order to improve the spatial self-organization of society that a system of bodies of state power and local self-government is formed, it enables the optimal combination of state administration and market regulation. Public geography in these conditions is intended to provide the theoretical and applied bases of territorial administration – management of the regions' development, to develop the scientific basis for the implementation of regional policy and the mechanism of its prediction.

Public geography, despite having a solid theoretical framework and concrete results of research in terms of improvement of various aspects of the territorial self-organization of society in Ukraine or its regions, cannot reach a qualitatively new level of its development, declare itself as a science, and, above all, cannot yet effectively solve a number of strategic issues of Ukraine's development in the context of its Eurointegration strategy. As O. Topchiiev observes, this is due to the small «mass» of social geographers in the state's scientific potential. Such problem can be solved only by the powerful scientific schools, which

have to integrate their efforts to produce the specialists in the field of human geography of the highest level of qualification. Scientific and education institutions and schools should build a strategy of dragging into the plane of their research a number of applied directions that have formed on the boundaries of human geography and other sciences and have the potential to implement the constructive function of socio-geographical science. First of all, it deals with geo-economics, geo-politics, geo-ecology, geo-informatics, and so on. Scientists should transfer qualitative and quantitative results of their research to the achievements of these studies on the plane of human geography– a unified science, the methodology of which is really based on the principles of territorial analysis of the self-organization of all spheres of society's life.

If we talk about the strategic directions of research development within these components, we should say that only geo-economics has already adapted to market conditions the theory of economic zoning and the theory of TPCs, the concept of PGC, which can offer results in terms of increasing the competitiveness of regions, industrial specialization and balanced development of regions, justify market infrastructure creation, territorial organization of industries and outline the growth poles. The examples of such implementation of research are doctoral theses by G. Pidhrushnyi «Industry and Regional Development of Ukraine (theory and practice of socio-geographical research)», Yu. Palekha, «Theory and Practice of Determining the Value of Territories and Estimating the Lands of Settlements of Ukraine (economic and geographical research)», S. Zapototskyi «Scientific Principles of Regional Competitiveness Formation: socio-geographical research», I. Pylypenko «Center-peripheral Processes and Structures in the Territorial Organization of Society», etc.

Based on the experience of comprehensive and systematic study of territorial human communities, human geography has already successfully investigated the quality of population's life at the level of doctoral researches (I. Hukalova, «Quality of Population's Life in Ukraine: Theoretical and Methodological Foundations of Socio-Geographical Research») and the problem of depression in the development of territories (M. Baranovskyi «Rural Depressive Territories of Ukraine: Theoretical and Methodological Principles of Socio-Geographical Research»), geography of culture (I. Rovenchak «Geography of Culture: Problems of Theory, Methodology and Research Methods»), geosophia (Yu. Kyseliov «Socio-Geographical Foundations of Theoretical and Applied Geosophical Researches in Ukraine»), geo-demography (V. Yavorska «Regional Geodemographic Processes in Ukraine: Theoretical and Methodological Aspects»), which has prospects for studying human spatio-temporal behaviour.

The research, carried out by the staff of the IG NAS of Ukraine under the leadership of L. Rudenko, is devoted to the analysis of the problem of interaction of nature and society in Ukraine in the twentieth century, demonstrates a successful synthesis of natural, socio-geographical knowledge and ecology, at the same time, it reveals the great possibilities of geographers in the development of geo-ecology problems, theoretically substantiates the processes of interaction of society and nature, the formation of the natural life environment. The fundamental nature of this research area , its justification and the determination of the priorities for its further development can be found in the following dissertations: S. Lisovskyi «Economic and Geographical Principles of Sustainable Development of Ukraine», L. Nemets «Socio-Geographical Bases of the Transition Strategy of Ukraine to the Model of Sustainable Development», S. Sonko «Theoretical Foundations of the Spatial Sociogeospheric Systems Formation in the Context of the Sustainable Development Concept of Ukraine», K. Nemets «Socio-Geographical Foundations of Sociogeosystems' Information Development», etc.

The geopolitical direction is based on the political geography theory, territorial management and forecasting, regional policy and state studies, planning and spatial regulation, and is vividly represented in doctoral studies by M. Dnistrianskyi «Ethnopolitical Geography of Ukraine: Problems of Theory, Methodology, Practice» and P. Shukanov «Socio-Geographical Features of the Global Civilization Space Formation». We have solid work in the field of public administration as well, in particular, it deals the justification of principles of regional development management, regional development forecasting (K. Mezentsev, «Socio-Geographical Forecasting of Regional Development: Theory, Methodology, Practice»), geoplanning (D. Malchykova, «Methodology and Geoplanning Methodology of Rural Areas at the Regional Level»), geospatial studies and space planning practices (E. Maruniak, «Socio-Economic Space (Methodology of Geospatial Research and Planning Practice)».

Consequently, the above-mentioned directions are and will be developing in the plane of the human geography object-subject sphere. They strengthen its internal principles, supplement the science with new theses aimed at the discovery of new laws and regularities of territorial processes of the interaction between society and nature, spatial life organization, functioning and development of territorial systems, as well as new paradigms, hypotheses, concepts, methods and forms of their organization.The development

of the principles of human geography will improve its methodology through the introduction of methods of geographic information systems and technologies, methods of spatial research, neural networks, mental mapping, etc. (Shevchuk,2017). On the other hand, such directions will promote the implementation of the applied function of science, related to the development of practical recommendations for improving the territorial self-organization of society.

Conclusions. Further realization of these tendencies in the national human geography requires clarification of its theoretical base in accordance with the realities of the beginning of the XXI century, at the same time it will contribute increased attention to the applied aspects of science and will protect it from pointless abstraction. The demands of society will influence the development of social geography, of course. In fact, these are the problems that require the immediate solution of scientific schools. The strategic goal is the determination of the economic, demographic, social, political and environmental capacities of the geographic shell, justification of rational parameters of regional and global nature management.The identification of the main trends of technological, sectoral and territorial development of the economy of Ukraine and its regions matter greatly. Raising the level and quality of life of Ukrainians; radical improvement of the technological structure of production and its transfer to an innovative level; definition and achievement of the optimal (for the modern stage of development of the country) social, functional-branch and territorial structure of the economy; optimization of the structure of economic, social, political and other relations are also considered to be the main tasks as well. The tasks of more active participation in solving the problems of nature use and conservation, the development of depressed regions, substantiation and implementation of regional economic, social, demographic and environmental policies are set before human geography at the regional and local levels. The key to solving these problems from the methodological point of view is the substantiation (using both domestic and world experience) of the general theory of regional studies taking into account the diversity of society's territorial organization.

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Neoproterozoic microbially-induced sedimentary structures (MISS) from Ediacaran Podillya Basin, Ukraine: mineralogical particularity and paleoenvironmental application

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Abstract. The Neoproterozoic Podillya sedimentary Basin is well known to the imprints of the Ediacaran soft-bodied fauna which were previously described by many ukrainian and foreign authors. At this period, fossil-rich siliciclastic sediments recognized as traces of early metazoans also contain evidence of significant microbiological activity. In these ediacaran sediments, many structures can be interpreted as microbially induced sedimentary structures (MISS). Their morphologies have a great similarity with modern structures observed in relation with micro-organism activity. These specific structure and surfaces and their mineral composition are the criteria used to study the bacterial structures from the ukrainian Neoproterozoic sedimentary basin. Our results demonstrate microorganisms were organized in bacterial mats whose activity was recorded in the difference of mineralogy between biological films and host rocks. On outcrop, the different type of MISS are often associated with lenticular beddings, ripples and hummocky cross structures indicative of coastal-marine conditions close to the littoral zone of the basin at this epoch. If MISS are important in the issue of paleogeographic reconstructions, they also give precious informations about early diagenetic processes, syn- and post-sedimentation. By mineralogical approach we show that during the time of development of MISS structures and the burial that followed the diagenetic processes have remained moderate. Finally, the close coexistence with ediacarian fossils suggest that such bacterial mats could be at the origin of the fossilization process of soft-bodies of enigmatic Ediacaran biota of Mohyliv-Podylska Group and their preservation until today.

Key words: Neoproterozoic, Ediacara, Vendian, MISS, bacterial activity, siliciclastic rocks

Неопротерозойські мікробактиріальні осадові структури (MISS) з Подільського басейну України: мінеральні особливості та палеокліматичне застосування

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Анотація.Неопротерозойський басейн Поділля добре відомий у світі завдяки відбиткам м'якотілої фауни едіакарського типу, які раніше були описані багатьма українськими та зарубіжними авторами. Кремнеземисті відклади неопротерозойського часу цього осадового басейну, окрім наявності макро-біоти, містять докази значної мікробіологічної активності. У цих осадових відкладеннях багато структур можуть бути інтерпретовані як бактеріальні осадові структури (MISS). Їх морфологія подібна до сучасних структур, що спостерігаються у безпосередній близькості з мікроорганізмами. Специфічна будова у поперечному розрізі, характер нашарування та мінеральний склад - ці критерії використовувалися у даній роботі для опису та аналізу бактеріальних структур з неопротерозойського осадового басейну в Україні. Наші результати показують, що макроорганізми були організовані в бактеріальних матах, активність яких була зафіксована в різниці мінерального складу між бактеріальними плівками та вміщуючими породами. На відслоненнях наявність лінзоподібних текстур, поверхневих текстур брижі та косошаруватих текстур, у комплексі з різними формами бактеріальної активності у Волино-Подільському басейні відповідає прибережно-морським умовам, близьким до прибережної зони басейну в цю епоху. Будучи важливим фактором у питанні палеогеографічних реконструкцій, MISS структури також дають цінну інформацію про діагенетичні процеси у товщі, син- та пост-седиментацію. У даній роботі демонструється метод вивчення мінерального складу бактеріальних матів для припущення

інтенсивності діагенезу під час формування MISS-структур; наявність змішаношаруватих глинистих фаз типу іллі т/смектит та іллі т/хлорит вказує, що діагенетичний вплив протягом Могилів-Подільського часу був помірним.
У даній статті описані бактеріальні структури в неопротерозойському осадовому басейні Волино-Поділля під час панування Едіакарської макро-біоти, а також охарактеризовані мінералогічні подібності та відмінності між мікробіальними матами та їх вміщуючими породами у кремнеземистих відкладах Могилів-Подільської серії.

Ключові слова: Неопротерозой, Едіакарська фауна, Венд, бактеріальні мати, осадові породи

Introduction. Microbially-induced sedimentary structures (MISS) occur in siliciclastic, shallow-marine settings throughout the geological record (Noffke, 2009). They develop during growth, metabolic activity, destruction and decay of microbial mats in siliciclastic-dominated environments (Hill et al., 2016). After Buick et al. (1981) and Noffke (2009), six criteria for biogenicity of MISS allow the exact distinction of MISS from similar but abiotic structures: a) they occur in rocks that have not undergone higher than low grade metamorphism; b) in stratigraphic section, they are located at turning points of regression-transgression; c) they appear in relation to the depositional "microbial mat facies"; d) their distribution reflects the average hydraulic pattern in a depositional area; e) the fossilized MISS shapes resemble in geometries and dimensions to modern ones; f) the MISS include microtextures that present, or were caused, or are related to ancient-biofilms and microbial mats. After Grazhdankin (2004), a biotic interaction of MISS could be decisive for distribution of Ediacaran macrobiota.

Since the mid-twentieth century, many recognized sedimentologists (Seilacher, 1946; Logan et al., 1964; Bromley, 1990) began to note that the presence of specific bacterial structures in sedimentary terrigenous rocks indicates a significant effect of biological processes during the sedimentation. Also, a detailed study of MISS-structures in terrigenous sedimentary paleo-basin could be used as an auxiliary factor for the reconstruction of paleo-conditions of sedimentary environments (Noffke, 2009; Hill et al., 2016).

Here we describe microbially induced sedimentary structures from the Volyno-Podillya sedimentary Basin. Identification of these structures is based on the six criteria for MISS biogenicity as outlined in Noffke (2009). In addition to the identification of structures, we analyzed both the mineral composition of the MISS structures and that of their host rocks in order to compare their respective mineralogical signatures. These new geological data provide important additional information on sedimentary processes and the paleo-environment during the Ediacaran period, a prelude to the "Cambrian explosion".

Geological setting. Located on the southwestern outskirts of the Ukrainian crystalline shield (Fig.1), the upper part of sedimentary basin of Podillya is stratigraphically related to the Upper Vendian - by the regional stratigraphic nomenclature, and to the Ediacaran - according to the international stratigraphic scale and confirmed by the recent results in determining the absolute age using bentonite layers from this basin (Soldatenko et al., 2019). The sedimentary cover is represented by the Upper-Ediacaran deposits, subdivided into Mohyliv-Podylska and Kanilivska Groups. In this paper, the lower term represented by the Mohyliv-Podilska Group will be considered in more detail. It is represented by siliciclastic sedimentary rocks affected by metamorphism of very low grade and presenting as such an excellent state of conservation. From bottom to top, this Group consists of three sequences of terranes (Palij, 1976, Velikanov et al., 1983) called: Mohylivska (FM), Yaryshivska (FY) and Nagoryanska (FN) Formations.

The composition of sedimentary deposits is characterized by interbedding of sandstone, siltstone and clayey facies. While MISS structures have been found in most of the Mohyliv-Podilska group, they are mostly abundant in siliciclastic deposits of the Mohylivska Formation (FM) where they overlap cyanobacterial structures very often (Fig. 2). On the other hand, it should be noted that the largest number of representatives of the Ediacaran macro-fauna in the whole Neoproterozoic basin of Volyno-Podillya (Palij, 1976) was detected precisely in the lower part of FM formation. In addition, in silty and clayey deposits (Nesterovsky et al., 2018) of the Nagoryanska Formation (FN) – also characterized by the unique presence in this basin of phosphate nodules (Velikanov et al., 1983; Nesterovsky and al., 2017) - there are also a large number of bacterial structures.

Material and Methods. To identify the bacterial MISS structures of the Volyno-Podillya Basin, we studied fifteen samples of the characteristic facies of the three main previous Formations: sandy-silts and siltstones facies (FM), sandstones and sandy siltstones (FY), claystones and clayey silts facies (FN).

The bulk and clay fraction of MISS-structures and of host deposits were determined by X-ray diffraction in laboratory of University of Poitiers. The bulk analysis was carried out on the material previously crushed and sieved at 50 μm and mounted in randomly ordered powder mode in order to characterize the reflections (hkl) of the minerals.

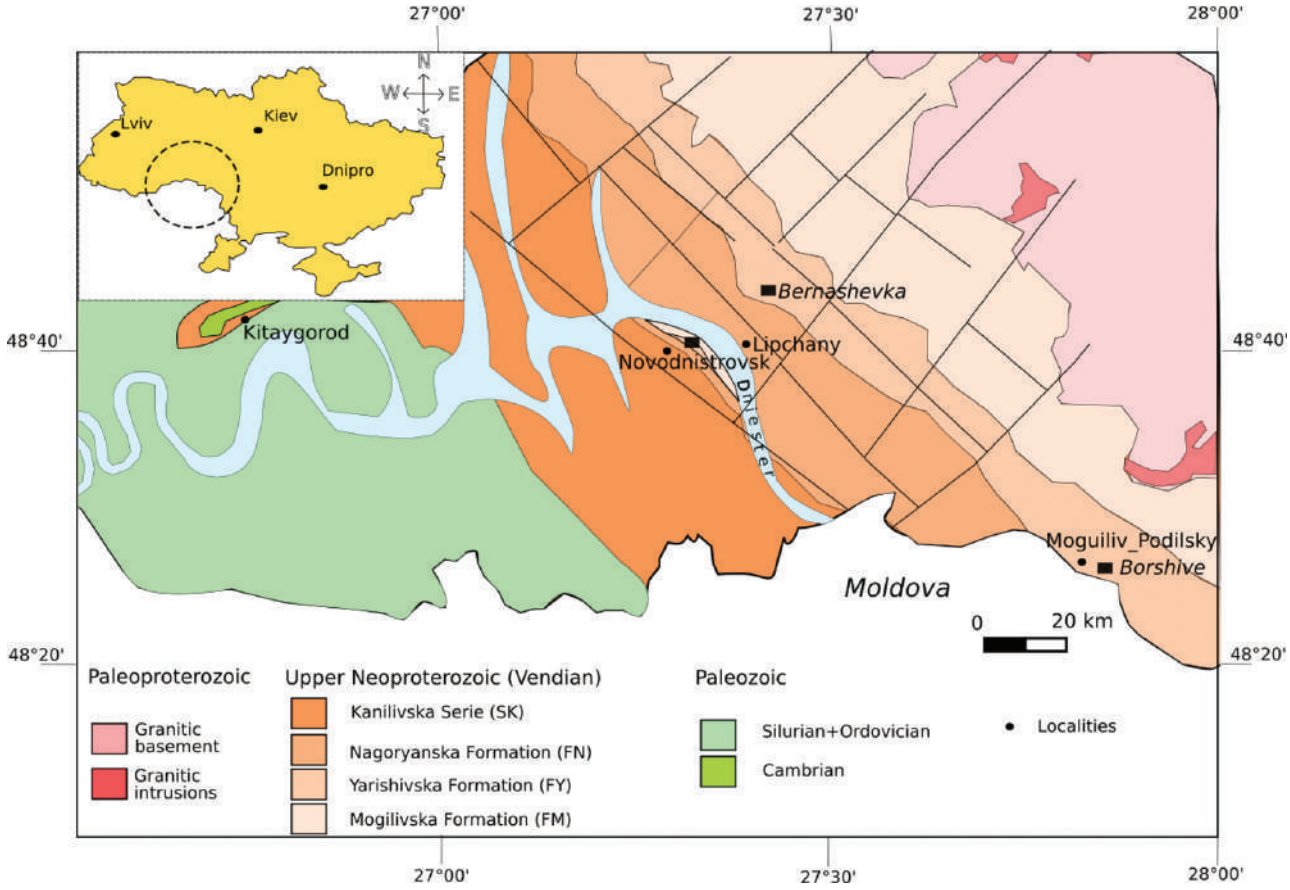

Fig. 1. Synthetic geological map showing the Paleozoic-Precambrian sedimentary cover and the Ukrainian Crystalline Shield.

The mineralogy of the fine fraction was previously separated by sedimentation after dispersion and then centrifugation at 20°C and 1000 s/min during 120 s using a centrifuge JOUAN GR 422. After drying, 15 mg of clay diluted in 1.5 mL of osmosed water and then deposited on a glass slide to study the position of the reflections (00*l*) during the treatments (drying, glycolage) described by Brindley & Brown (1980) et Moore & Reynolds (1989). The X-ray diffractogramme were obtained using a Bruker D8 advance A25 diffractometer, equipped with a copper source (($\lambda_{CuK\alpha}$ = 1.5418 Å) and controlled by the software Diffract Suite© v11.0.8 (2009). Its optical system consists of an anti-divergence slot of 0.11 °2θ, an anti-diffusion slit of 0.11 ° 2θ, two Soller slits and a Kβ filter of nickel. The analytical conditions are 40 kV and 40 mA; acquisition parameters are 1s for a step of 0,025 °2θ for angular ranges of 2-65 °2θ and 2-30 °2θ, in powder and oriented respectively.

Results.

1. Basic characteristics of the bacterial structures from the Neoproterozoic Volyno-Podilsky Basin. Proofs of microbial activity in the Vendian sedimentary rocks of the Volyno-Podillya Basin are found in all terrigenous sediments, starting from the FM and FY Formations in coarse and medium grained deposits of sandstones and sandy siltstone. MISS structures are often associated with imprints of the Ediacaran macrofauna, but very often they can completely form they own surface structures (Fig. 3). In the upper FN Formation, the imprints of typical Ediacaran macrofossils practically disappear, while the presence of microbial structures becomes dominant. By instance, browned silty claystones of this Formation are often covered with a thin microbial layer, which partly determines the wave-like surface of deposits (Fig. 3A, B). Sometimes microbial structures are characterized by brown and greenish-brown shades in layering, and black spots on this surface (Fig. 3C); in other cases, these bacterial structures are characterized by repeating ornaments on the surface of sediments (Fig. 3D). In the vertical section, the microbial mats correspond to thin clayey layers; these layers are most often represented as separate fragments of clay sedimentary material preserved in the sandy siltstone (Fig. 3E, F).

2. Mineral composition of bacterial mats and their host rocks. Five samples from FM, FY, FN Formations were selected for detailed study of the mineral composition of bacterial mats and host rocks (Fig. 4).

The mineral composition of sedimentary deposits containing MISS structures is characterized by the presence of quartz, feldspars and mica minerals; as

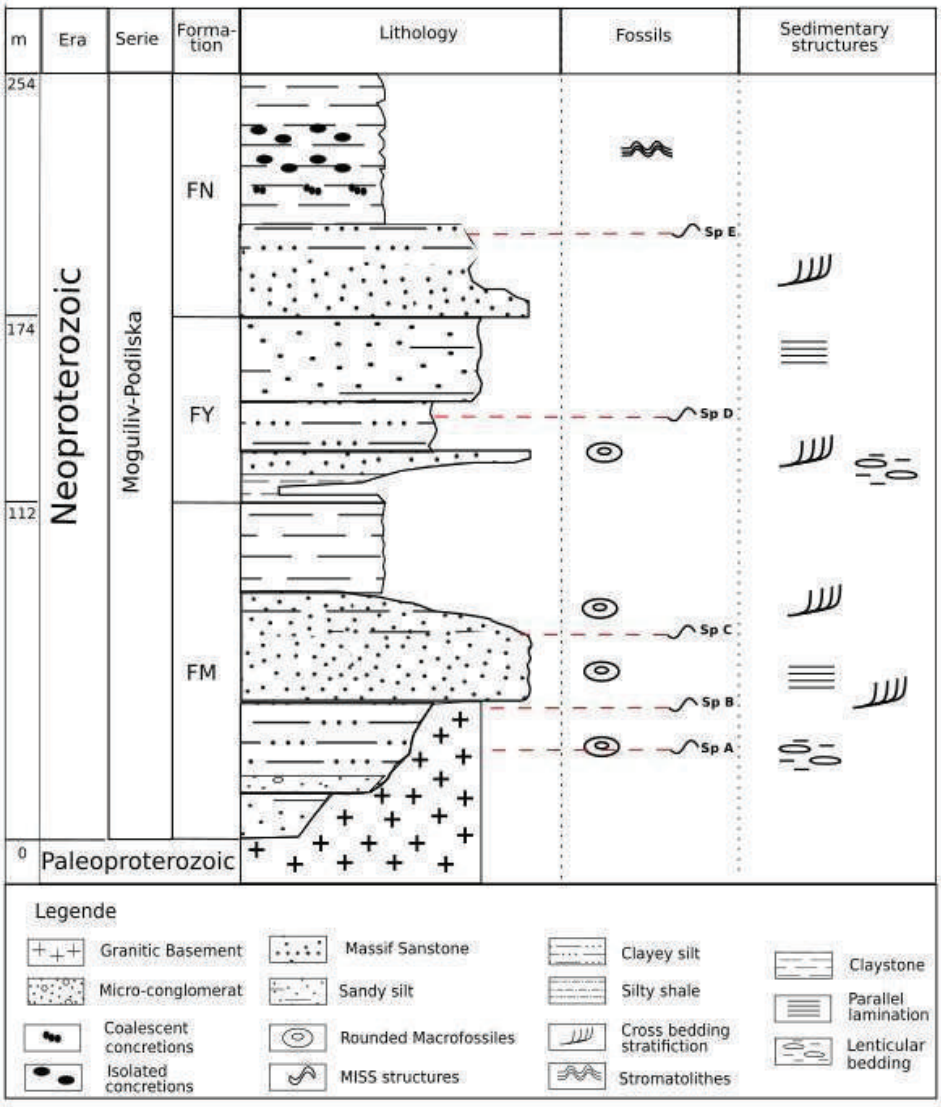

Fig. 2. Stratigraphic column (after Velikanov et al., 1983, Bratslavsky et al., 2008) showing the lithological succession in the Moguiliv-Podilska Neoproterozoic Series of Southern Podolya basin, and detailed locations of sampling for this work (Sp A - Sp E).

for clay minerals, the main representatives are illite, chlorite, illite/smectite mixed-layer and sometimes kaolinite, which can be a secondary product of weathering of feldspars. The mineral composition of the MISS structures from those rocks is identical to the qualitative index, however, the peaks of the clay components become much more intense; in addition, mixed-layers become dominant, as indicated by more intense and broad peaks on diffractograms (Fig. 5).

MISS structures in sediments from the FM Formation appear in the form of thin clayey films covering the surface of siliciclastic rocks (Fig. 4A), sometimes coinciding with "wrinkled" surfaces (Fig. 4B, C). For this Formation, sandy siltstone and medium-grained sandstones are gray, greenish with blue shades. The main mineral phases of bacterial structures in these sediments are chlorite (peaks 14.20 Å and 7.08 Å), biotite and illite with a high degree of crystallization, which indicates an acute form of peak at 10,0 Å, as well as a mixed-layer illite/smectite (10.50 Å) (Fig. 5A, B, C). A characteristic feature from FM Formation in two cases - host rocks and their MISS structures - is the presence of a specific mixed-layered phase of illite/chlorite (11.70-12.00 Å and 8.37 Å); in this case, this rare mineral phase is associated with sandy-siltstone, which includes the largest number of imprints of the Ediacaran fossils in the Volyno-Podillya Basin. Finally, other mixed-layer of illite/chlorite-type is almost equal to the percentage of each clay component.

In the FY and FN Formations MISS structures are traced in the form of brown surface films on siltstone deposits of greenish-brown color. By opposite, for the FY Formation, the layering patterns are more typical (Fig. 4D), whereas in the FN Formation bacterial structures manifest themselves as scaly plating, slightly bubbly on their surface (Fig. 4E). If the mineral content of the host rock and MISS structures

Fig. 3. Vendian deposits from sedimentary Formations of Volyno-Podillya basin showing MISS structures on their surfaces: A, B, C - siltstones from FN Formation (48°53', 27°48'); D - sandy silts from FM Formation (48°40', 28°00') ; E, F - vertical section of silty sandstones from FM Formation (48°59', 27°46') whose contain clayey microbial micro-layer.

is compared, in the case of the Sp D, the peaks of chlorite (14.30 Å), mica (10.00 Å) and kaolinite (7.15 Å) are present in both samples, while feldsapths, K as Ca,Na-rich (6.49 Å and 6.38 Å), are completely absent in the mineral composition of the bacterial mat (Fig. 5D). Concerning the illite/smectite mixed

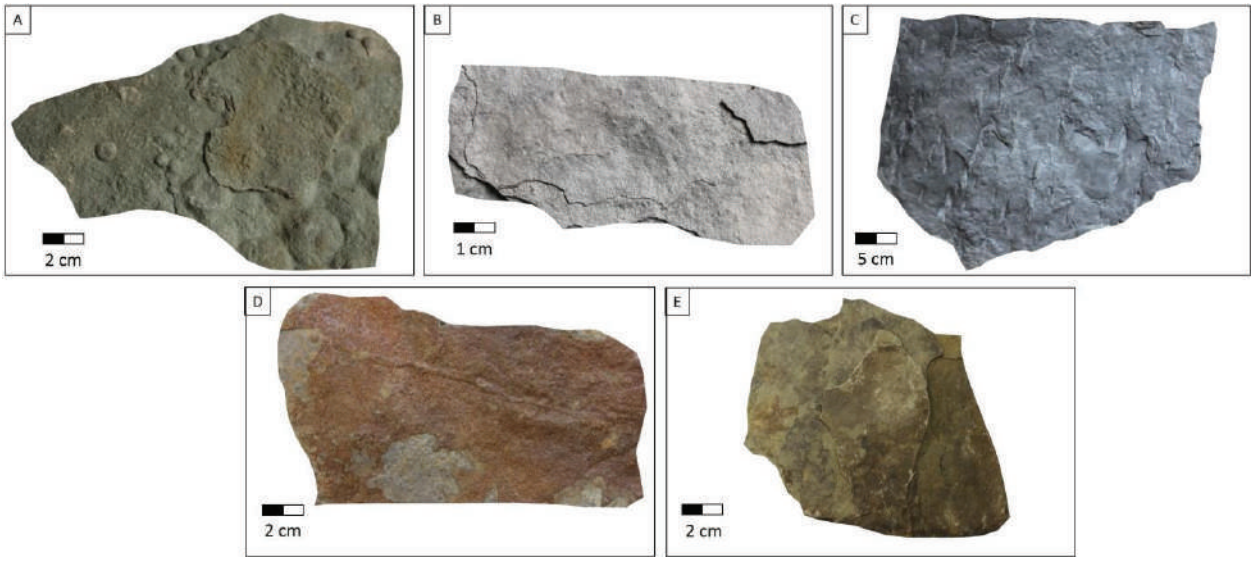

Fig. 4. Samples from Ediacaran deposits selected for mineralogical analysis from sedimentary Podillya basin with MISS structures on their surfaces: A, B, C - sandy silts from FM Formation (48°59', 27°46'); D - siltstone from FY Formation (48°46', 27°78'); E - clayey silts from FN Formation (48°53', 27°48').

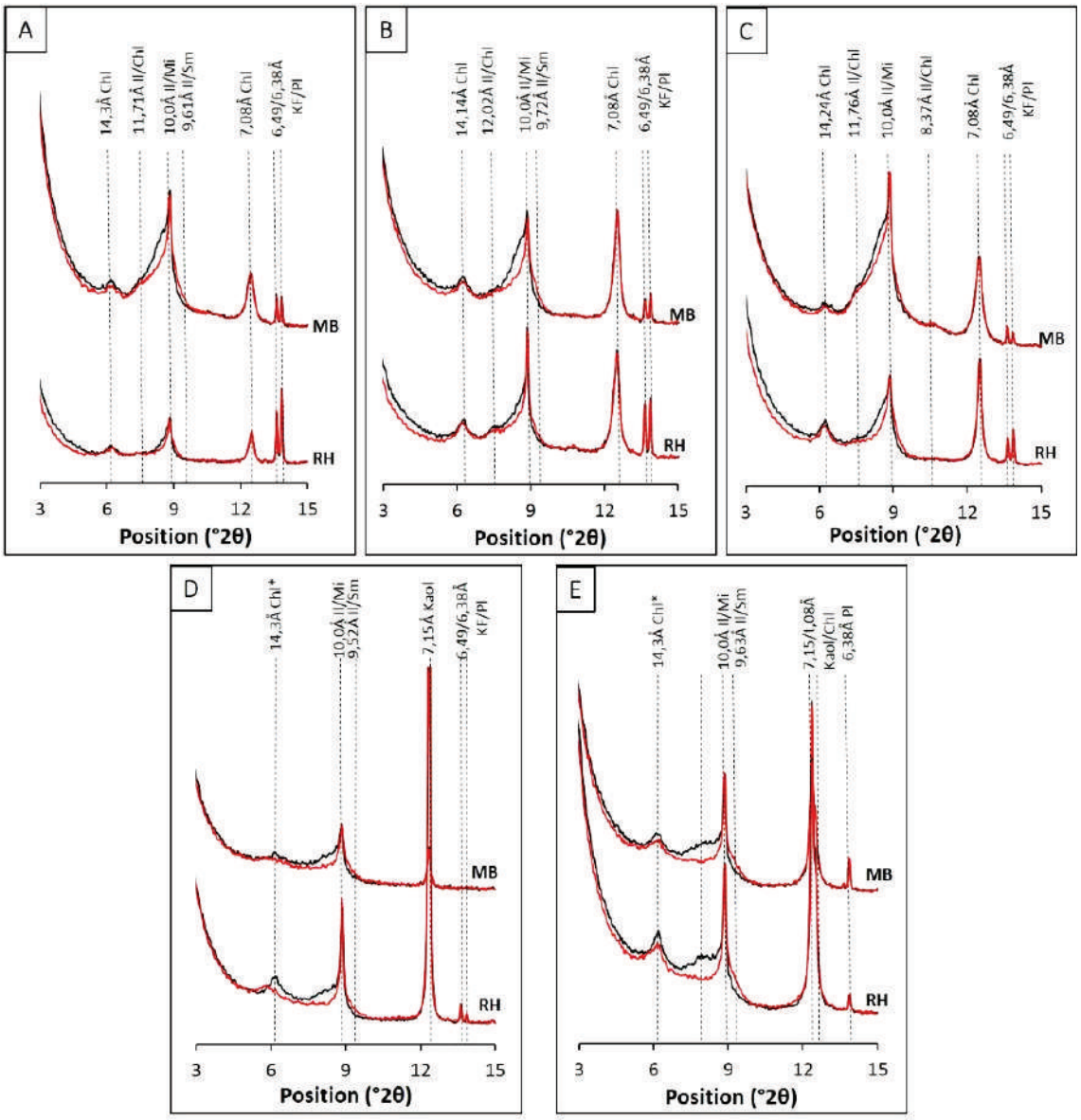

Fig. 5. Diffractogram patterns of bulk sample (oriented preparation) in air dried (black) and ethylene glycol solvated treatment (red) of: A) Sp A from FM Formation; B) Sp B from FM Formation; C) Sp C from FM Formation; D) Sp D from FY Formation; E) Sp E from FN Formation. Identified minerals: (KF) K-feldspar; (I/C) illite/chlorite mixed-layer; (Chl) chlorite; (I/S) illite/smectite mixed-layer; (K) kaolinite; (M) mica; (P) plagioclase.

layer, it is present in samples of the host rocks, and in samples of bacterial mats from the FY and FN Formations (Fig. 5D, E).

In the deposits of whole FM Formation, it should be noted that the shift of the position of the major peak for illite/smectite mixed-layer after ethylene glycol solvation (Fig. 5A, B, C) indicates higher smectite content in the interstratification. On the contrary, the illite/smectite mixed layers of samples from FY and FN Formations show a less significant swelling effect (Fig. 5D, E) indicative of their more illitic character. Finally, the other mixed-layer of illite/chlorite-type, which was characteristic for FM Formation, is no longer present either in the rocks or in the levels of bacterial mats in the deposits of FY and FN Formations (Fig. 5D, E).

MISS structures - mineralogical particularity and paleoenvironmental application. The presence of MISS structures in the siliciclastic sediments of the Volyno-Podillya Basin serves as a reliable criterion for the conditions of sedimentation during the Late Neoproterozoic time. Together with the appearance of numerous sedimentary structures in all Formations of the Mohyliv-Podilsky Group (ripples, HCS), bacterial MISS structures reflect moderately deep basin with an active hydrodynamic regime that corresponds to the coastal-marine conditions of the littoral zone. For assumptions about the depth of this paleobasin, it should be taken into account that bacterial structures could dominate at depths that are within the reach of the photic zone. More generally, the presence of Ediacaran fauna in the basin, and their association

with bacterial structures in particular (Nesterovsky et al., 2018) are also additional indicators of moderate depths and reach of the photic zone.

An important role of bacterial mats could be to facilitate the preservation of external morphological features of macrobiota (Aubineau et al., 2018). Most likely, MISS structures have become a kind of elastic interlayer, composed of clay material. Proceeding from the fact that the sedimentary conditions during the prosperity of the Ediacaran fauna were mostly active and the nature of the sediments was from medium to coarse-grained, the clayey characteristic of bacterial mats became the most suitable for preserving the soft-bodied fauna (Samanta et al., 2015). In the other hand, thanks to the presence of the bacterial mats the process of "biostabilisation" of the siliciclastic rock also took place (Kovalchuk et al., 2017).

Also, bacterial mats can be used as an additional criterion for moderate impact of diagenesis. The mixed layer illite/chlorite was detected in the sediments of that section, which corresponds to the maximum amount of the Ediacaran biota in the Podillya basin. According to Ahn et al. (1988), such a rather rare clay phase as illite/chlorite mixed layer is very sensitive to temperature changes and high pressure actions. Lee and Peacor (1985) also found that the chemical difference between these two phyllosilicates, respectively di- and trioctahedral, would result in a significant mis-fitting at the interface. Therefore, the illite/chlorite mixed layer is structurally unstable, and consequently, it can be saved exclusively in rocks that have undergone the minimal transformations after sedimentation.

Conclusion. MISS structures are of a great importance to determine the state of the bottom environment from the Neoproterozoic sedimentary Podillya basin. There, such structures were distributed in different parts of the littoral zone and at present they characterize the facial conditions of sedimentation.

A good preservation of Ediacaran macrobiota in Podillya basin is mainly due to the dispersed (clayey) substrate composition formed during the development of MISS structures, in combination with their sandy-silty overlapping deposits.

Sediments, in which bacterial structures were buried, did not undergo significant post-sedimentary changes. It is characterized by the presence of illite-smectite and illite-chlorite mixed-layer components in the matrix of these structures.

The study of substrate from the accumulation of microbial mats in conjunction with geological features of coastal-marine lithogenesis (ripples, HCS) provides new opportunities for paleogeographic reconstruction of the basin, in which the first soft-bodied multicellular organisms appeared.

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Spatially distributed GIS-realized mathematical model of rainstorm erosion losses of soil

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Abstract. In connection with the wide and ever increasing spread of erosion degradation of agricultural lands in Ukraine, the task of developing mathematical models and methods for calculating water erosion of soils corresponding to the current level of erosion study and the demands of soil protection practices is becoming increasingly important. The article is devoted to the development of a spatially distributed GIS-implemented mathematical model of rainstorm soil erosion, which accounts for most of the annual soil losses (in the Steppe zone, for example, about 90 %). The development of the model is based on the most theoretically and informationally grounded model for the Steppe and Forest-Steppe of Ukraine , "the logical-mathematical model of rainstorm soil outwash" developed by H. I. Shvebs (1974, 1981), as well as the results of theoretical and field studies and mathematical modeling of the slope runoff and water erosion of soil, carried out at the Department of Physical Geography and Environmental Management of Odessa I. I. Mechnikov National University in the 1990s - 2010s, and also the possibilities of modern geoinformation technologies. For the spatial implementation of the model, a raster model of spatial data and operators of the PCRaster GIS-package (University of Utrecht, the Netherlands) were used, integrated with the Basic programming language into a single system that provides an implementation of the computational algorithm. The developed physical-statistical model of soil erosion-sedimentation takes into account the peculiarities of the formation of slope runoff and soil outwash in conditions of excessive nonstationarity of heavy rainfall, as well as spatial heterogeneity of all major natural and economic factors of water erosion on a slope, including slope steepness, exposure, longitudinal and transverse forms of slopes, soil erodibility, structure of sown areas and anti-erosion measures. Checking the adequacy of the mathematical model was performed using observational data of four experimental catchments ; two runoff plots of the Moldavan water-balance station with total area of 0.08 ha, the Ploska catchment with area of 8.5 ha (Boguslav field experimental base of Ukrainian Hydrometeorological Institute) and the Sukha catchment with area of 63 ha (Veliko-Anadol water-balance station) with observation periods of 17-31 years. Comparison of the calculated average over the catchment area of mean annual values of rainstorm soil losses, with the corresponding values obtained from measurements on these catchments, made on the basis of Nash-Sutcliff efficiency criterion (NS), allowed us to evaluate the quality of the model as good (NS = 0.72).

Keywords: water soil erosion, mathematical model, GIS-implementation, model verification

Просторово-розподілена ГІС-реалізована математична модель зливових ерозійних втрат ґрунту

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Анотація. У зв'язку із широким і постійно зростаючим розповсюдженням ерозійної деградації сільськогосподарських земель в Україні, все більш актуальною є задача розробки математичних моделей і методів розрахунків водної ерозії ґрунтів, відповідно до сучасного рівня розвитку ерозієзнавства та запитам практики ґрунтозахисного землеробства. Стаття присвячена розробці просторово-розподіленої ГІС-реалізованої математичної моделі зливових ерозійних втрат ґрунту, на частку яких припадає більша частина (у степовій зоні – близько 90 %) річних втрат ґрунту. в основу розробки моделі покладена «логіко-математична модель зливового змиву ґрунту», розроблена Г. І. Швебсом (1974, 1981), а також результати теоретичних і польових досліджень та математичного моделювання схилового стоку і водної ерозії ґрунтів, виконаних на кафедрі фізичної географії і природокористування Одеського національного університету імені І. І. Мечникова у 1990-і – 2010-і роки, а також можливості сучасних геоінформаційних технологій. Для просторової реалізації моделі використана растрова модель просторових даних і оператори ГІС-пакету PCRaster (Університет м. Утрехта, Нідерланди), інтегровані за допомогою мови програмування Basic у єдину систему, що забезпечує реалізацію розрахункового алгоритму. Розроблена фізико-статистична модель змиву-акумуляції ґрунту враховує особливості формування силового стоку та змиву ґрунту в умовах підвищеної не стаціонарності випадіння зливових опадів, а також просторову неоднорідність всіх основних природних та господарських факторів водної ерозії на схи-

лі – ухилу схилу, експозиції, поздовжньої та поперечної форми схилів, протиерозійної стійкості ґрунтів, структури посівних площ і протиерозійних заходів. Перевірка адекватності математичної моделі виконана з використанням даних спостережень у межах чотирьох експериментальних водозборів із площами 0,08 га (дві стокові ділянки Молдавської водно-балансової станції), водозбір улоговина Плоска із площею 8,5 га (Богуславська польова експериментальна база Гідрологічного інституту України) і водозбір Сухий із площею 63 га (Велико-Анадольська водно-балансова станція) із періодами спостережень17-31 рік. Зіставлення розрахованих осереднених за площею середньо багаторічних значень зливових ерозійних втрат ґрунту із відповідними значеннями, отриманими за даними вимірювань на цих водозборах, виконане на основі критерію ефективності Неша-Сатклiффа (NS), дозволило оцінити якість моделі як добру (NS=0,72).

***Ключові слова**: водна ерозія ґрунту, математична модель, ГІС-реалізація, верифікація моделі*

Introduction. In accordance with (Natsionalna dopovid…., 2010), the area of eroded land in Ukraine is about 16 million hectares, which is 38.4% of the area of agricultural land .The area of eroded arable land is about 13 million hectares or 39.9% of its square. In many administrative regions, especially in the Steppe zone, these figures are significantly higher. So, in the Dnipropetrovsk region 43.8% of the agricultural land area is eroded, in Odessa region – 46.8%, in Kirovograd region – 54.0%, in Lugansk region – 71.8%, in Donetsk region – 85.9%. Over the past decades, the area of eroded land in the country has been constantly increasing and this is largely due to the growth of the areas of mostly medium and strongly eroded soils. As noted by the authors (Kanash & Osipchuk, 2003), a steady trend has arisen towards increase in the area of medium eroded soils by an average of 18.9 thousand hectares, strongly eroded soils - by 5.2 thousand hectares a year. The erosion degradation of soils is associated with the deterioration of their water-physical and chemical properties, biological activity and decrease in fertility. Products of erosion destruction of the soil cover are the process of siltation of river valleys, deterioration of the quality of surface water, etc. The final result of the development of soil erosion is desertification.

With the spread of soil water erosion in almost all natural zones of Ukraine, the permanent expansion of eroded land, the problem of protecting agricultural landscapes from the damaging effects of soil erosion is becoming increasingly important. The designing of anti-erosion measures is based on mathematical models of erosion losses of soil. The practice of conservation agriculture in the United States and many other countries is based on the use of the modern version of the Universal Soil Loss Equation (RUSLE) (Renard et al., 1991) and its modifications – MUSLE, USLE-M, RUSLE-3D. Other mathematical models are also used, in particular, KINEROS and KINEROS2 (Smith et al., 1995), LISEM (De Roo et al., 1996), WEPP (Ascough et al., 1997), EUROSEM (Morgan et al., 1998), EROSION 2D/3D (Schindewolf & Schmidt, 2012). However, for the natural-economic conditions of Ukraine, these models are not parameterized, often do not have the necessary information support, and have not been verified.

In the 1970s – 90s in Ukraine a number of mathematical models of soil erosion losses were developed with varying degrees of theoretical validity and information provision, which were used or recommended for anti-erosion design purposes. Among them, the most famous are: "logical-mathematical model of erosion losses of soil", developed by H. I. Shvebs (Shvebs, 1974, 1981), "mathematical-statistical model of soil erosion losses during heavy rainfall", developed in the former Ukraine Research Institute for Soil Erosion Protection (Lavrovskiy et al, 1987; *Spravochnik*..., 1990) and the formula of I. K. Sribnyi (Sribny, 1977; Sribny & Vergunov, 1993). It should be noted that all these models belong to the category of models with lumped parameters, that is, they operate with average values of input data for the territory under consideration (length and slope, characteristics of the soil cover, agricultural background and anti-erosion measures), and the result of the calculation is the average value of soil erosion rate for the area. At present, it is generally recognized that the optimal system of anti-erosion measures is a soil-protective landscape-adaptive farming system, taking into account the specific features of the structure and functioning of the agrolandscape. The design of such systems requires the use of spatially distributed mathematical models of soil erosion, taking into account the spatial differentiation of all the main factors of the slope erosion-sedimentation process.

The development of such a model was performed during the 1990s - 2010s at the Odessa I. I. Mechnikov National University, Department of Physical Geography and Environmental Management. The development is based on the logical-mathematical model by H. I. Shvebs (Shvebs, 1974, 1981), as well as on the basis of results of researches and modeling of storm soil erosion and surface runoff formation under conditions of their pronounced nonstationarity on slopes of complex longitudinal and transverse shape using the capabilities of modern

geo-information technologies (Svetlitchnyi, 1995, 1999; Svetlitchnyi et al., 2003; Pyatkova, 2008, 2013). The resulting spatial version of the model is a physical-statistical mathematical model of erosion-sedimentation, which makes it possible to calculate for a given point of the slope not only the average long-term amount of erosion losses of soil, but also deposition of sediments.

The purpose of this article is to summarize the results of research on the spatial GIS implementation of the model on slopes of complex transverse shape and model verification using long-term monitoring of sediment runoff on catchments of various sizes. *The object* of research is the slope water-erosion process, which causes erosion degradation of agro-landscapes. *The subject* of research is spatial implementation and verification of the physical-statistical mathematical model of soil erosion losses using geo-information (GIS) technologies.

Material and Methods. The article is based on the results of theoretical and field studies and mathematical modeling of water soil erosion, performed at Odessa I. I. Mechnikov National University (Shvebs, 1974, 1981; Svetlitchnyi, 1995, 1999, Chorny, 1996; Svetlitchnyi et al., 2004; Pyatkova, 2008, 2013)

For the spatial GIS-implementation of the model, a raster spatial data model, analytical capabilities of the PCRaster Environmental Modeling Package (GIS-package) (PCRaster…, 2018) and the programming language Basic were used.

The verification of the model was carried out using the materials of long-term observations on the slope watersheds and runoff plots at runoff and water-balance stations of the Hydrometeorological Service of Ukraine and Republic of Moldova.

The methods used are comparative-geographical, statistical, graph-analytical, geographic information mapping and mathematical modeling,

Results and Discussion. GIS-implementation of the model on the basis of raster model of spatial data assumes that each cell of the digital raster map with *i, j* coordinates is considered as the outlet of the catchment of this cell. The catchments of individual cells, which in the environment of the PCRaster package identified as "cell upstream elements", we shall call "partial catchments" or "sub-catchments".

Calculated expressions of the spatial version of the physical-statistical mathematical model of soil erosion-sedimentation in this case take the form:

for $x \le L$

$$W_S(i,j) = 2{,}6\cdot 10^{-6}\left[\left(1+0{,}5\left(\frac{x'}{x}\right)^{0,5}\right)K_{HM}(i,j)\,j_R(i,j)I^m(i,j)f_a(i,j)\,x^{0,5} + \right.$$
$$+K_{HM}(i,j)\,j_R(i,j)I^m(i,j)\frac{df_a(i,j)}{dn}\,x^{1,5} + K_{HM}(i,j)\,j_R(i,j)\frac{dI^m(i,j)}{dn}\,f_a(i,j)\,x^{1,5} + \quad (1)$$
$$+K_{HM}(i,j)\frac{dj_R(i,j)}{dn}\,I^m(i,j)f_a(i,j)\,x^{1,5} + \frac{dK_{HM}(i,j)}{dn}\,j_R(i,j)\,I^m(i,j)f_a(i,j)\,x^{1,5} +$$
$$\left.+K_{HM}(i,j)\,j_R(i,j)I^m(i,j)f_a(i,j)\,x^{1,5}\,\frac{d(x'^{0,5})}{dn}\right],$$

for $x > L_a$

$$W_S(i,j) = 2{,}6\cdot 10^{-6}\left[\left(1+0{,}5\left(\frac{x'}{x}\right)^{0,5}\right)K_{HM}(i,j)\,j_R(i,j)I^m(i,j)f_a(i,j)L_\Delta{}^{0,5} + \right.$$
$$+K_{HM}(i,j)\,j_R(i,j)I^m(i,j)\frac{df_a(i,j)}{dn}\,x + K_{HM}(i,j)\,j_R(i,j)\frac{dI^m(i,j)}{dn}\,f_a(i,j)\,x + \quad (2)$$
$$+K_{HM}(i,j)\frac{dj_R(i,j)}{dn}\,I^m(i,j)f_a(i,j)\,x + \frac{dK_{HM}(i,j)}{dn}\,j_R(i,j)\,I^m(i,j)f_a(i,j)\,x +$$
$$\left.+K_{HM}(i,j)\,j_R(i,j)I^m(i,j)f_a(i,j)\,x\,\frac{d(x'^{0,5})}{dn}\right],$$

where $W_s(i, j)$ is a long-term average soil losses, t/ha/yr, in the cell with coordinates (i, j); x is the distance from the watershed to the cell (i, j) along the local drain lines, m; x' is the modified distance from the watershed to the cell (i, j) along the local drain lines, m; $K_{HM}(i, j)$ is an average value of the hydrometeorological factor of rainstorm erosion of soil within the sub-catchment of the cell (i, j); $j_R(i, j)$ is an average value of the characteristics of relative soil erodibility within the sub-catchment of the cell (i, j); $f_a\, i, j)$ is an average value of the agro technical factor within sub-catchment of the cell (i, j); $I(i, j)$ is an average slope steepness within the slope micro catchment above the cell (i, j), ‰; L_a is the length of the zone of increase in the intensity of soil washout which is adjacent to watershed of the slope, m; L_Δ is the length of the zone of increase in the intensity of soil washout within the sub-catchment of the cell (i, j) when $x>L_a$, m; m is the exponent at a slope steepness, for non-eroded and light eroded chernozems and forest soils equal to 1.30, for medium and strongly eroded equal to 1.35.

The modified distance from the watershed to the cell (i, j) along the local drain line x´ is calculated by the equation:

$$x' = 0{,}5x\left[K_f(i, j) + 1\right], \qquad (3)$$

where K_f is the coefficient of development of the form of sub-catchments which takes into account the degree of concentration of surface flows, dimensionless.

The coefficient of development of a sub-catchment's form characterizes the degree of deviation of the width of the sub-catchment from some average value at a given length of the sub-catchment ("standard") for the given geomorphological and soil-climatic conditions. It is determined by the ratio of the sub-catchment's width B of a given cell with coordinates (i, j) to the width of a standard sub-catchment the same length B_{st}.

The inclusion of the coefficient of development of the sub-catchment's form into expressions (1) - (2) allows us to take into account the structure of surface flows. First, the value of the coefficient K_f characterizes a greater ($K_f > 1$) or lesser ($K_f < 1$) concentration of surface flows with respect to the "standard" conditions, increasing or decreasing the modified slope length x′. To an even greater degree, the concentration of surface flows is taken into account by calculating the first derivative of the modified length of the slope along the streamline. If the value of the derivative is positive, the transverse concentration of surface flows increases, if the value is negative, the concentration of flows decreases. This is especially important for the so-called converging slopes. However, experience has shown that in order to take into account the concentration of surface flows, in this case, a detailed hydrologically correct DEM is necessary and that the raster cell size does not exceed 10 m.

The value of the L_a, as the length of the zone of growth of intensity of sediments formation from the watershed down the slope is calculated by the formula arising from the formula of the rate of surface flows from the normative document (Pravila…, 1987)

$$L_a = 0{,}854\, k_v\, m_c^{\frac{3}{2}} \left(r_{\tau, p\%}\, \varphi\, b_c\, I_a\right)^{\frac{1}{2}}, \qquad (4)$$

where k_v is the coefficient taking into account the discrepancy between the velocity of flow and velocity of runoff wave, equal to 1.5; $r_{10,p\%}$ is the maximum average intensity of the 10% probability of rainfall for a ten-minute time interval, mm/min, for Steppe and Forest Steppe of Ukraine equal to 2.1 mm/min; m_c is a surface roughness coefficient, dimensionless; φ is the runoff coefficient, dimensionless; b_c is an average width of sub-catchment, m; I_a is an average slope steepness, ‰.

The flowchart of the GIS-realized model is presented in Fig. 1. The model consists of several blocks within which the corresponding calculations are performed.

Input data for calculations of average annual rainstorm erosion soil losses within the study area is:

1) hydrologically correct digital elevation model;
2) map of slope's watersheds;
3) map of genetic types and subtypes of soils;
4) eroded soils distribution map;
5) maps of land use with borders of crop rotation fields, information on crops and technologies of their cultivation and erosion control measures;
6) value of the norm of the hydrometeorological factor of rainstorm soil losses, obtained on the basis of observation data at the nearest meteorological station or taken from the map (Svetlitcnhyi et al.,2004);
7) value of moisture of the half-meter soil layer at the flat place according to observations of nearest agrometeorological station.

The soil moisture map is calculated using a sub model presented in (Svetlitchny et al., 2003). The model is founded on the dependence of the soil moisture on the form of the slope, its exposition and remoteness from the divide. The model is fully implemented in the environment of the PCRaster package.

The transition from soil moisture to the index of

antecedent moisturizing which is required to calculate the hydrometeorological factor of soil losses (K_{HM}), is carried out with the help of dependence obtained using data of observations for soil moisture at agrometeorological stations of Ukraine (Svetlitchny & Ivanova 2004). The dependence between the moisture of the upper half-meter soil layer (W) and index of antecedent moisturizing (I_W) is described by

$$I_W = 59{,}2\left(\frac{W - W_{MH}}{W_{MC} - W_{MH}}\right) + \frac{71{,}3 - W_{MH}}{4{,}08}, \quad (5)$$

the following expression:

where W_{MC} is the field capacity and W_{MH} is the maximum hygroscopicity of the upper half-meter layer of soil, mm.

At each calculation step, the values of variables I, j_R, K_{HM}, f_a, m_c, φ, b_c are averaged within the sub-catchment of the given cell. The problem of variable averaging is solved under GIS-implementation of the model by using the Basic programming language integrated with operators of the PCRaster package.

In this way, the GIS-implemented spatially-distributed physical-statistical model of rainstorm erosion-sedimentation of soil allows us to take into account the main features of the formation of rainstorm surface runoff, the influence of steepness, length, and longitudinal and transverse curvature of slopes as well as the spatial variability of natural and anthropogenic factors of soil erosion on slopes.

Verification, that is, in this case, the establishment of its truth, adequacy, is a necessary and mandatory step in the development of any mathematical models. However, it should be noted that, as applied to mathematical models designed to estimate the norm (mean multiyear value) of soil erosion losses, this rule is not always fulfilled. The problem is that in Ukraine there is not a sufficient number of field stations with long-term and reliable observations of

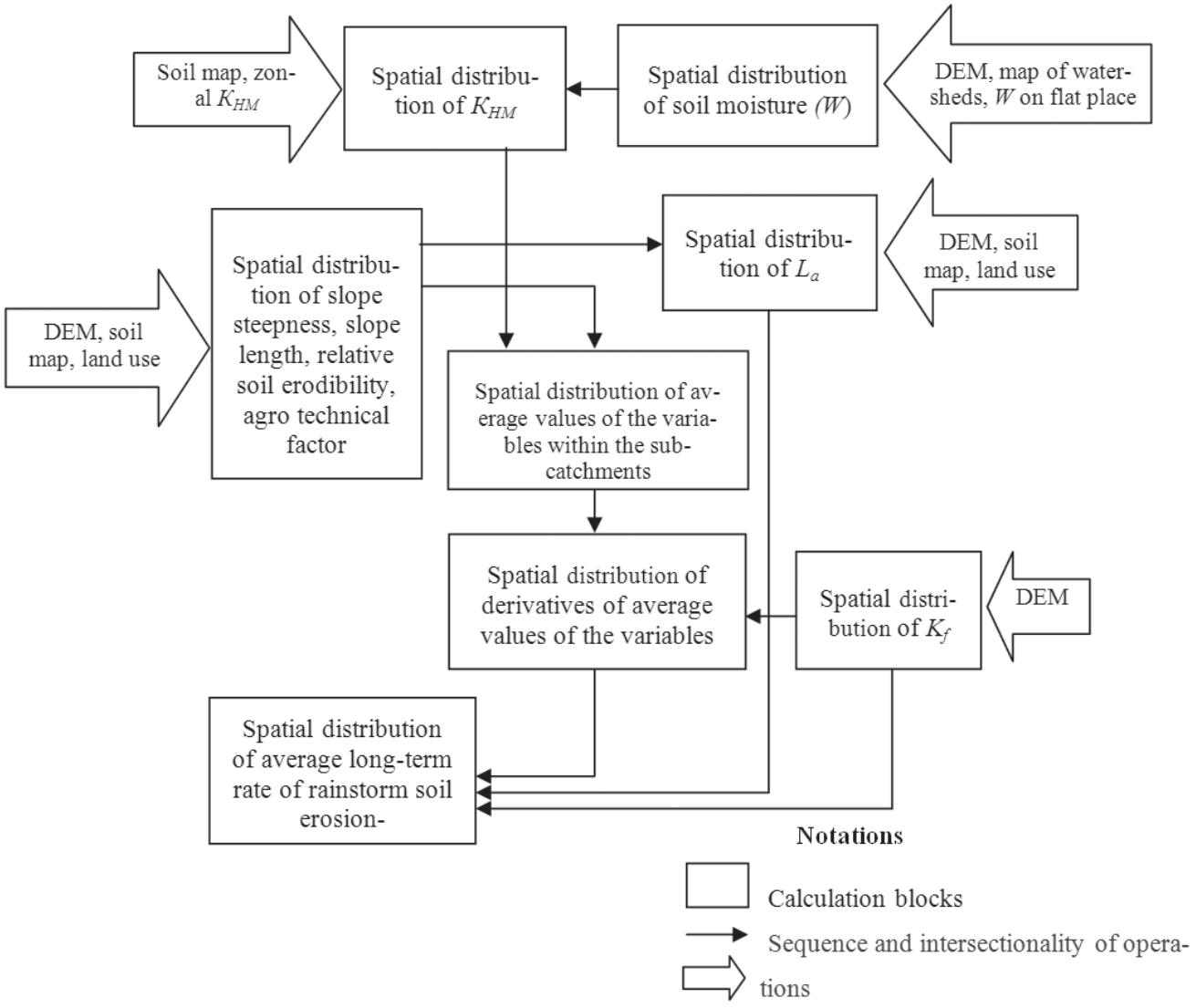

Fig. 1. Flowchart of calculation of average long-term rate of rainstorm soil erosion-sedimentation

the erosion process on slopes, such as, for example, in the USA and in some other countries. Practically the only source of such data is observations at Runoff and Water-Balance Stations at runoff plots and small catchments without pronounced thalweg or with thalweg, the slope of which is not significantly different from the slope of the catchment. On such catchments, sediment yield is recorded only in their outlets and, from the point of view of evaluating models of erosion soil losses on slopes, it is important that deposition of slope sediments does not occur in thalwegs, which is inevitable if the slope of thalweg is substantially less than the slope of adjacent slopes.

territory of Republic of Moldova, showed that from the experimental catchments with long periods of observation of the storm-washout of the soil, only the catchment Ploska of Boguslav FEHB, catchment Sukha of Veliko-Anadol WBS and runoff plots No.1 and No.2 of Moldavan WBS satisfy the formulated conditions (Tab. 1). There are no thalwegs on the Ploska catchment and on the runoff plots, there is a thalweg 0.74 km long on the Sukha catchment, but the average thalweg slope of 21.6 ‰ differs slightly from the average slope of the catchment equal to 23.4 ‰.

The Ploska catchment (Fig. 2) is the upper channelless part of the slope of a small right tributary

Table 1. Characteristics of the test catchments

Catchment	Period of observations	Number of years	Area, km^2	Length, m	Average slope of catchment, ‰	Average slope of thalweg, ‰
Ploska, Boguslav FEHB[1]	1970-1987	18	0.085	450	24.7	-
Sukha, Veliko-Anadol WBS[2]	1956-1987	31	0.63	740	23.4	21.6
Runoff plots No.1 and No. 2, Moldavan WBS	1963-1982	17	0.0008	40	111	-

[1]Boguslavskaya Field Experimental Hydrological Base of Ukrainian Research Hydrometeorological Institute;
[2]Veliko-Anadol Water-Balance Station, Donetsk region;
[3]Moldavan Water-Balance Station, Republic of Moldova.

Analysis of materials of the Pridesnyanskaya Runoff Station, the Veliko-Anadol Water-Balance Station, the Boguslav Field Experimental Hydrological Base of the Ukrainian Research Hydrometeorological Institute, located within the territory of Ukraine, and the Moldavian Water-Balance Station located relatively close to the borders of Ukraine on the

of the Butenya River (tributary of the Rosava River, the right tributary of the Dnieper River), within the Boguslavskiy district of Kyiv region. Its area is 8.5 ha; the average slope is 24.7‰ (Tab. 1). Maximum slope is 54.4‰. Slope exposition is northern. Soils are dark grey forest podzolized, coarse-dusty light loamy, mostly non-eroded, lightly and medium eroded in the

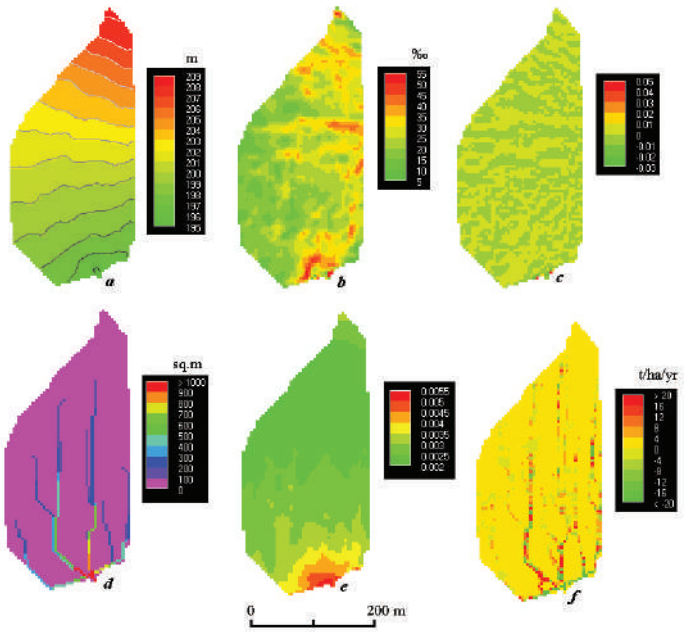

Fig. 2. Main input, derivatives and resultant digital maps of the Ploska catchment: a – digital elevation model; b – slope steepness map; c – slope longitudinal curvature map; d – upstream elements map (shows a surface flow structure); e – the hydrometeorological factor map; f – soil losses map

lower part only. During the period under consideration, the surface of the Ploska site was fully ploughed and used for cultivation of agricultural crops as one crop rotation field (winter wheat - 47 % years, corn – 28 % years, sugar beet – 14 % years, as well as peas and perennial grasses – 5 % years each).

The size of the raster for all digital maps of the catchment which are used for calculation of the soil losses rate is 90 x 140. The size of the cell is 5 m.

catchment of the Veliko-Anadol Water-Balance Station located in Donetsk region, is a left-bank tributary of the Sukha Volnovaha river (the Kalmius river basin). The catchment area is 0.63 km^2, thalweg length is 0.8 km, the average width of the catchment is 0.57 km, the average slope of the thalweg is 21.6 ‰, average catchment slope is 23.4 ‰. The soil cover of the catchment is homogeneous and is represented by ordinary chernozem, which thickness is 50-75 cm.

Table 2. Comparison of calculated and actual average annual rainstorm soil loss by test catchment

Catchment	Average annual soil loss, W t/ha/yr		Calculation error, %
	actual	calculated	
Ploska, Boguslav FEHB	0.33	0.60[1]/0.39[2]	81.8/18.2
Sukha, Veliko-Anadolskaya WBS	0.16	0.12[1]	-25.0
Runoff plot No.1, Moldavan WBS	6.24	8.19[1]	31.3
Runoff plot No.2, Moldavan WBS	7.6	10.6[1]	39.5

[1] calculated using the zonal norm of the hydrometeorological factor of rainstorm soil loss;
[2] calculated using the average for the period of observations on the catchment of the hydrometeorological factor, calculated according to the nearest weather station data.

The zonal value of the hydrometeorological factor is 0.0033. The main input, derived and resulting digital maps are presented in Fig. 2. The value of the calculated average annual soil losses is 0.60 t/ha/year, while the value of actual soil losses measured in the outlet during a 17-year period is 0.33 t/ha/year (Tab. 2). A characteristic feature is the distinct alternation of soil outwash and soil sedimentation along the lines of surface runoff concentration. In some cells of the raster, the estimated soil outwash reaches 130 t/ha/yr and sedimentation – 280 t/ha/yr.

The Sukha test catchment is an experimental

Brown loam lies below, turning into yellow clay at a depth of 100-150 cm.

During the period under consideration, the catchment area was almost completely used for growing crops – winter wheat, barley, oats (44 % of the area), corn (22 %), annual and perennial grasses (22 %), vegetable crops (9 %), on average 3 % of the area was occupied by fallow.

In Fig. 3 a screenshot of the PCRaster working window with the result of calculating the rate of storm soil losses within the Sukha catchment in tons per hectare on average per year with superimposed

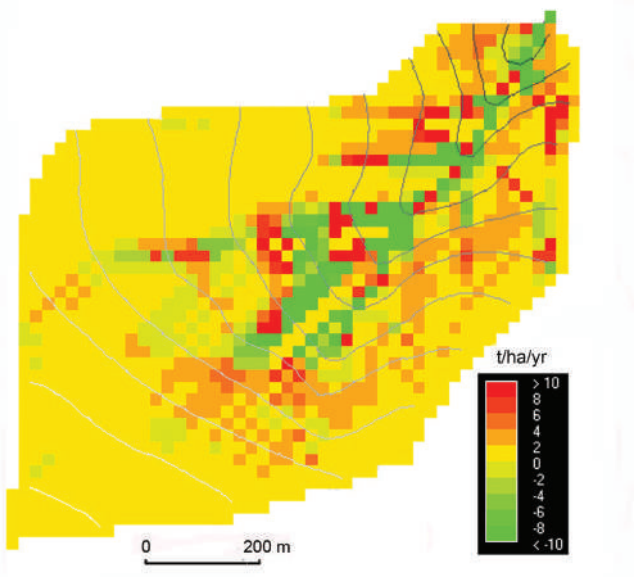

Fig. 3. Map of the calculated norm of erosion-deposition (t/ha/yr) within the Sukha catchment, Veliko-Anadol Water-Balance Station

contour lines of relief after 2 m is presented. The averaged over area annual soil loss is 0.12 t/ha/year, which is very close to the average annual soil loss determined from observations on the catchment for 31 years (0.16 t/ha/year). Attention is drawn to the significant accumulation of sediments in the thalweg, despite the fact that its slope is quite comparable with the average slope of the catchment.

Runoff plots No.1 and No.2 of the Moldavan Water-Balance Station, which is located in the central part of the Republic of Moldova, 18 km south-east of Chisinau, during the period under consideration, were used for growing crops in crop rotation. In the summer period, plot No.1 was occupied by corn during 47 % of years, by melon crops – 13 % of years, by oats – 7 % of years, by beans – 6 % of years and by fallow-27 % of years (f_a = 0.68). Plot No.2 during the most part of the period under consideration in the summer was under fallow (during 67% of years), under corn – 13 %, under oats – 7 %, under leguminous crops – 7 %, under melon crops – 6 % of years. (f_a=0.85).

Due to the small size of the plots (40x20 m), the lack of data of detailed relief survey, the calculation of the rate of soil losses for the plots was done using average values of length, slope, soil cover and agricultural background characteristics, and zonal value of the hydrometeorological factor (Svetlitchnyi et al., 2004). The calculated values of the soil loss for the plots exceed the actual ones by 31.3 % and 39.5 % (Tab. 2). For the calculation of soil erosion losses, such accuracy can be considered acceptable. The obtained values of erosion soil losses with sufficient accuracy from a practical point of view characterize the intensity of erosion processes and can be used to assess the erosion hazard of the territory, and to justify the soil protection measures.

But it should be noted that, on the magnitude of the calculation error in this case could have had an impact , on the one hand, the use of averaged over the area values of input variables, and, on the other, using of zonal value of the norm of the hydrometeorological factor of rainstorm soil erosion. Zonal value of the KGM were obtained based on the use of meteorological observation data at the reference meteorological stations of the Steppe and Forest-Steppe zones of Ukraine for 1949-1989, followed by a generalization of the results of calculations for individual meteorological stations within homogeneous regions using the ergodicity hypothesis (Svetlitchnyi, 1995; Svetlitchnyi et al., 2004). It is likely that the perennial mean value of the hydrometeorological factor for the period of observations at the test catchment differs from the zonal norm.

So, the perennial mean value of the hydrometeorological factor for the catchment, calculated for the period 1970-1987 using data of the nearest meteorological station Boguslav amounted to 0.0019, while the zonal value is equal to 0.0033. Accordingly, the calculated average value of soil loss using this perennial mean value of the hydrometeorological factor has been obtained equal to 0.39 t/ha/yr, which is much closer to the actual (0.33 t/ha/yr) than using the zonal K_{HM} value.

Comparison of calculated and actual values of mean annual erosion losses of soil for all test catchments is presented in Table 2. Given the large amplitude of the soil loss rate, to assess the accuracy of the model it is advisable to use not the mean square error of calculations, but more informative criterions, taking into account the increased variability of the annual soil losses. For four test catchments, for example, the minimum and maximum averaged over the area values of the annual rainstorm soil losses (0.16 and 7.60 t/ha/yr) differ by almost 50 times.

To assess the quality of the developed model we use the Nash-Sutcliffe (NS) efficiency criterion (Nash & Sutcliffe, 1970), which according to (Vinogradov & Nikiforovskiy, 2015) is currently the most popular criterion among specialists in mathematical modeling. The use of this criterion, in particular, is recommended by the American Association of Civil Engineers to assess the viability of runoff models. It is actively used to estimate mathematical models of water soil erosion (Van Rompaey et al., 2003; Wang et al., 2018 etc.). In the general case, the quality of the model is considered satisfactory for NS> 0.5, for 0.65 <NS ≤ 0.75 - as good and at 0.75 <NS ≤ 1.00 - as very good.

The NS criterion is calculated according to the formula

$$NS = 1 - \frac{\sum_{i=1}^{n}\left(W_{i\,act} - W_{i\,calc}\right)^2}{\sum_{i=1}^{n}\left(W_{i\,act} - \bar{W}_{i\,act}\right)^2}, \qquad (7)$$

where $W_{i\,act}$ and $W_{i\,calc}$ are the actual (observed) and the calculated values of the variable;

$\bar{W}_{i\,act}$ is average actual value of the variable;

n is a number of values of the variable.

The value of the Nash-Sutcliff criterion for the developed model based on the results of the calculation for the four test catchments is 0.72, which makes it possible to evaluate the quality of the model as good.

Conclusions. 1. The GIS-implemented physical-statistical model of erosion-sedimentation takes into account the main features of rainstorm surface runoff and soil erosion on the slopes of the Steppe

and Forest-Steppe zones of Ukraine, including slopes with a complex shape of a longitudinal and transverse profile. The conditions limiting the account of influence of the transverse concentration of surface runoff by the model are the presence of a detailed hydrologically correct digital elevation model and the raster cell size of not more than 10 m.

2. Practically the only source of data that allows assessment of the adequacy of soil erosion models in the natural-economic conditions of Ukraine remains the observational materials at the Runoff and Water-Balance stations of the Hydrometeorological Service, which were collected in the 1960–1980s..

3 The performed verification calculations of soil erosion losses for two runoff plots of the Moldavan Water-Balance Station and two small catchments of the Boguslav Field Experimental Hydrological Base and Veliko-Anadol Water-Balance Station, with observation periods of 17-31 years, made it possible based on the Nash-Sutcliff criterion to assess the quality of the developed model as good.

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History of economic development and forest land-use in the Fako-Meme forest region of Cameroon

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Abstract. The article is devoted to investigating a number of issues within the forest landscape of the Fako-Meme, south west region of Cameroon. An assessment of the history of economic development and use of forest in the studied territory was carried out. It was observed that the rate at which these forests are been hewn down for various purposes under the pretext of development leaves much to be desired. The deforestation of the forest with the attendant problems of resource degradation, environmental mutation is a cause for alarm. In order to understand the mutations taking place in the forest landscape, the history of forest use in 4 different periods: 1) the pre-colonial era (before the arrival of European explorers), (2) German colonial rule (1884-1916), (3) British colonial rule (1916-1961) and (4) Independence and post Independence Cameroon (1961-present day). It was observed that during the pre-colonial era the forest landscapes were very stable. Forest degradation in the territory started with the introduction of extensive mechanized agriculture introduced by the colonial masters through the opening of large agro-industrial plantations of rubber, palms and bananas. This forest ecological region suffers from a number of challenges. These problems were investigated in detail with proposals made for the sustainable management of forest resources in this forest ecosystem situated in the heart of the humid tropical region of the South West of Cameroon. These forests provide for a wide range of human needs ; medicine, timber , fuel wood, non- timber forest products (NTFPs), food crop production and cash crop cultivation. The pattern of land-use change in the Fako-Meme region was studied in three distinctive periods (1978, 2000 and 2015). The results revealed that anthropogenic activities have been systematically raping the forest landscapes so that the environments are only a skeleton or shadow of their former selves. This is an ecological region in which forest gives way to farmlands and plantations. In this respect, we see that what was a forest landscape in the past is now consisting of a succession of cocoa farms, palm, rubber as well as other economic cash crop plantations, with cocoa being the most important cash crop in the region. Evidence from our analysis reveals that this region has lost 42% of its forest cover within the period 1978-2015. This dynamic can be considered catastrophic. If this trend continues uninterruptedly in the region, then in 60-70 years, the Fako-Meme and the slopes of Mount Cameroon will remain without forest. It is easy to imagine the consequences of this. The study calls for urgent adaptive environmental strategies for the sustainable management of forest and its resources in the region.

Key words: History, economic development, forest land use, deforestation, Fako-Meme region, Cameroon

Історія господарського розвитку та лісовикористання у лісовому регіоні Фако-Меме, Камерун

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Анотація. Стаття присвячена дослідженню ряду проблем лісових ландшафтів Фако-Меме, південно-західного регіону Камеруну. Проведено оцінку історії господарського розвитку та використання лісів в районі дослідження. На основі аналізу було виявлено, що швидкість з якою вирубують ліси для різних цілей під приводом розвитку, залишає бажати кращого. Вирубка лісу призводить до деградації природних ресурсів, мутації навколишнього середовища. Для того, щоб краще зрозуміти, які зміни відбулися у лісовому ландшафті ми виокремили періоди освоєння та використання лісів Фако-Меме: 1) використання лісу у доколоніальну епоху (до прибуття європейських дослідників); 2) німецьке колоніальне правління (1884-1916 рр.); 3) британське колоніальне правління (1916-1961 рр.); 4) незалежний Камерун і до нині. Встановлено, що в доколоніальну епоху лісові ландшафти були дуже стабільними. Деградація лісів на території почалася з впровадженням великого механізованого землеробства, введеного колоніальними господарями за допомогою відкриття великих агропромислових плантацій каучуку, пальм і бананів. Разом з цим лісовий природний регіон зіштовхнувся з низкою проблем. Ці проблеми були детально вивчені з пропозиціями, щодо сталого управління природними ресурсами в лісовій екосистемі, яка розташована в центрі вологого

тропічного регіону на південному заході Камеруну. Ці ліси забезпечують потреби людей, починаючи від медицини, деревини, паливних ресурсів, недеревних лісових товарів (НДЛТ), виробництва продовольчих культур і вирощування товарних культур. Характер змін землекористування в регіоні Фако-Меме вивчався на прикладі трьох відмінних періодів (1978, 2000 і 2015 роки). Результати показали, що антропогенна діяльність систематично знищує лісові ландшафти. Фако-Меме – це природний регіон, в якому ліс поступається місцем сільськогосподарським угіддям та плантаціям. У цьому відношенні ми спостерігаємо, що в минулому лісовий ландшафт складався з ряду ферм: какао, пальм, каучуку, а також інших економічно вигідних товарних культур, причому какао було найважливішою економічно вигідною культурою в регіоні. Детальний аналіз показав, що цей регіон втратив 42% свого лісового покриву за період 1978-2015 рр. Цю динаміку можна вважати катастрофічною. Якщо така тенденція буде тривати в регіоні й надалі, то через 60-70 років Фако-Меме та схили гори Камерун залишаться зовсім без лісу. В такому випадку легко уявити наслідки цих дій. Вирішення даної проблеми в регіоні, потребує прийняття невідкладних адаптивних екологічних стратегій для сталого управління лісами та їх ресурсами.

Ключові слова: історія, господарський розвиток, лісокористування, вирубка лісів, район Фако-Меме, Камерун

Introduction. The tropics harbour a major proportion of the planet's forest resources. The Fako-Meme region falls into this zone. The Fako-Meme region of Cameroon geographically lies between latitudes 3° 86``–5° 4`` N and longitudes 9° 28``– 9° 49`` E (Fig. 1). It has a surface area of (5,200 km^2) with a forest-adjacent population of about 300,000 inhabitants. The overexploitation of these forest landscapes have yielded great benefits to the local populace living within the forest limits but the beneficiaries have not made commensurate investments for a rational use of these forest resources.

A handful of authors have examined the state of the forest landscapes in little patches and the results of their findings have been recorded as follows. (Hedberg, 1964) noted that Mount Cameroon, which

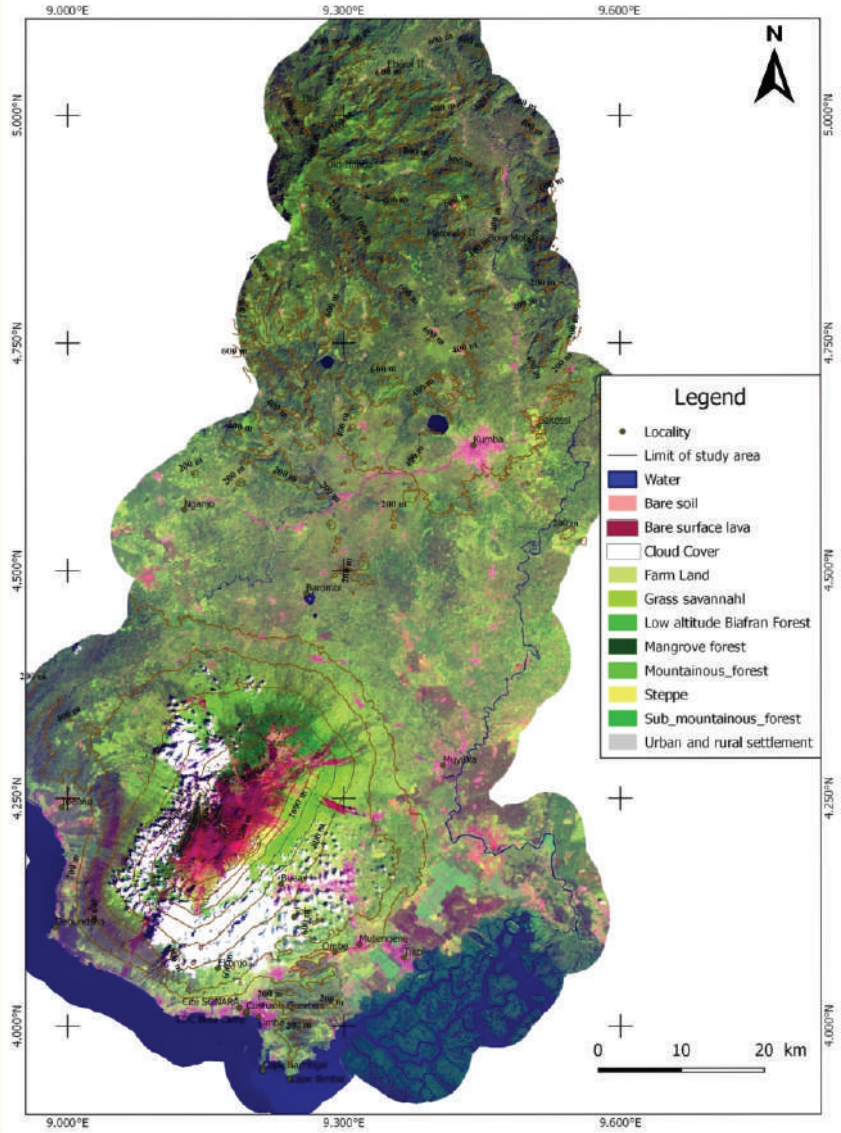

Fig.1. The Satellite Image of the Fako-Meme Forest Region

is an intergral part of the Fako-Meme region, is in the same volcanic chain as the Islands of Bioko (Equatorial Guinea), the Oceanic islands of Sao Tome, Ascuncion and Principe as well as Mount Kupe, Manenguba. The Rumpi Hills in Cameroon has an endemism of about 70% on the highland areas UNCLEAR. This view was equally supported by the opinion that the Mount Cameroon region of Cameroon, aside from South Africa, with its Campo region, is the most biologically rich region on the continent (Letouzey 1968, 1985). The region provides a biological mosaic that contributes to extremely high diversity in the Guineo-Congolian regional area of endemism, and it is regarded as one of the main Pleistocene refugia postulated for Africa (Gartlan, 1989).

The massifs and surrounding foothills of Mount Cameroon contain about 4,000 higher plant species and an estimated 50 of these are endemic to this region. This is the last area in Africa where natural vegetation remains unbroken from lowland forest at sea level to the sub-alpine grassland at the summit. However , it has been noted that this region has recorded significant damage to its ecosystems in the last several decades following the unsustainable use and exploitation of natural resources on the pretext of development (Kah, 2000; Balgah, 2001, 2005; Kometa, 2001; Yerima & Ranst, 2005; Bokwe, 2008, 2013; Mbella, 2011).

This region is estimated to be at the 3rd stage of development (Take-off stage) according to the Rostow Model of Economic Development. This view coincides with several case studies (Lambi & Kah, 2012, Lambi & Muete, 2016; Lambi et al., 2016; Njabe, 2013; Mukete, 2016 a,b; Mukete, 2017a, b; Mukete et al.; 2016).

These authors have directly or indirectly x-rayed the frustration and traumas happening in the forest landscape of this environment. But despite these laudable efforts, the Fako-Meme forest region has not been given the attention it deserves from policy makers. Since a hungry man is an angry man, the forest-adjacent communities which solely depend on the forest resources for their livelihood, have aggravated the stress and negative implications imposed upon the environment. It is therefore, critical that a more detailed assessment of the history of economic development on the one hand and the use of forest on the other be examined. This article is original and has brought a scientific contribution in the study of forest degradation in the territory. For the first time that the forest landscape has been studied with the use of satellite images comparing anthropogenic activities as presented by the author within three distinct periods (1978, 2000 and 2015).

The goal of the study was to analyze the history of economic development and use of forest in the Fako-Meme region of Cameroon within the time frame of 1978-2015. The study examined the anthropogenic mutations which have reshaped and transformed the natural forest landscapes into cultural landscapes.

Materials and Methods. Taking into consideration the holistic nature of the forest landscapes in the Fako-Meme region, the use of remote sensing materials was indispensable. Landsat ETM image Files of 1978, 2000 and 2015 were downloaded from the Global Land Cover Facility website and the various bands for each year were modulated and corrected to reveal settlement, roads, farmlands and other geographic features using ENVI 4.3. Open street maps were also downloaded using Global mapper 15 to help reveal the road network, names of towns and villages in that area. Visible features of interest were digitized and their shape files exported to ArcGIS 10.2, where they were assembled together with the raster and elevation data to produce the various maps as JEPG files. The polygons representing the various parameters were measured using ArcGIS 10.2 and displayed in the form of bar charts using M.S excels 2013. Hence, the methodology was grouped under data collection and data analysis with the use of descriptive, comparative, analytic, cartographic, fieldwork and camera methods of geographical research. Information from available literature and field survey formed the main source of data collection.

Results and Discussion. Understanding the history of economic development and use of forest resources in the Fako-Meme region, necessitated a review of pre-colonial era, the colonial era, independence and post independence Cameroon.

History of forest land-use. The Fako-Meme region falls within the then Southern Cameroon territory. Today it is situated in the southwest region of Cameroon. This region has witnessed four stages of economic and political development, which altered the socio-economic conditions of natural resources management. These periods of change correspond to certain historical developments in the terrotory (Fig. 2): The pre-colonial period (before the arrival of the German colonists); the German colonial period (1884-1916); the British and French Protectorates (1916-1961); the post independence development (since 1961). Such periodization is usually recommended in landscape studies as it depicts a systematic and chronological impact on the management of natural resources. During these periods we saw the introduction of agro-industrial plantations,

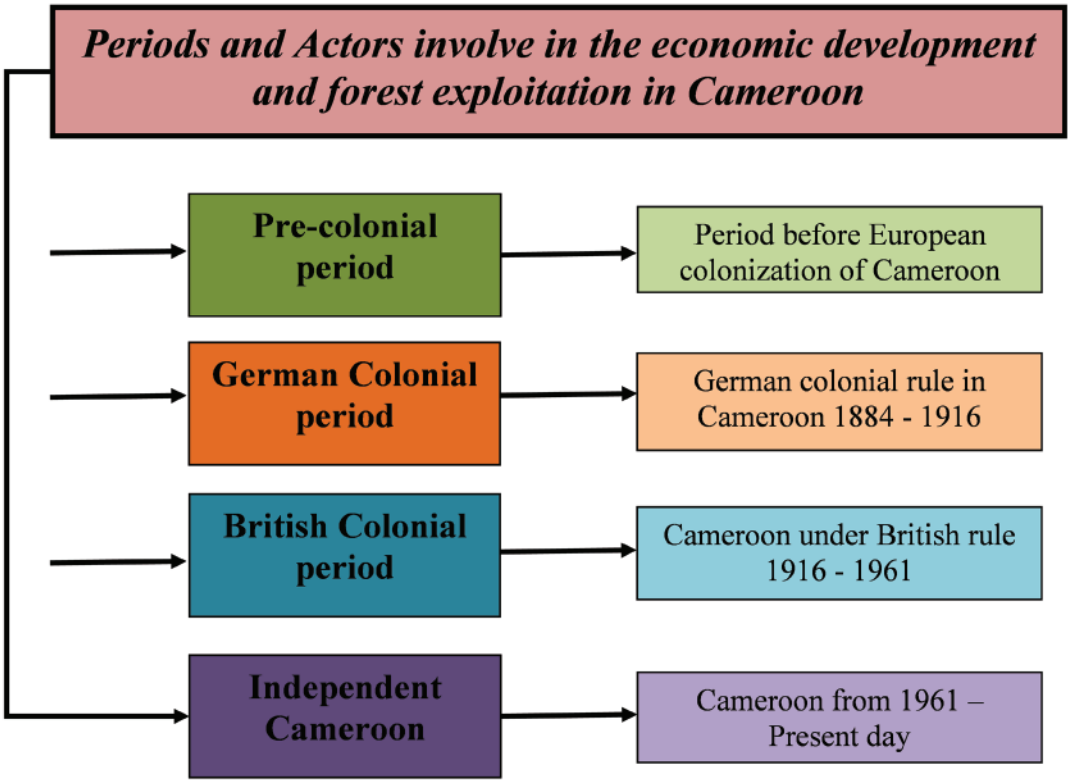

Fig. 2. The periods and actors involved in economic development and forest exploitation in Cameroon

construction of camps for agro-industrial workers, building of gigantic infrastructures, development of roads and railways with other social facilities, which cannot be over emphasized. The sum total of these activities was the gradual opening up of the forest landscapes. Today we witness a steady rape of the forest landscapes which remain only a skeleton of themselves. All this is happening under the pretext of development and the need to feed the burgeoning population using unsustainable agricultural practices.

Pre-colonial Period: The first forest dwellers were hunter-gatherers highly skilled in taking advantage of their forest habitat. They lived in small communities and used tools made of wood and stone and cooked their food over fires. These early populations who still live in the region are 'insultingly referred to as 'pygmies' because of their uncommonly short height. The economy in the Cameroon forest zone at this time was based primarily on shifting cultivation, hunting and gathering. The basis of this subsistence economy was the banana – plantain. These staple crops were introduced into Cameroon through the Bantu migration sometime after the last millennium, and were well established in the south west centuries before European contact. Cassava and cocoyam are native to Latin America and Asia respectively, and were probably introduced to West Africa by Portuguese and British traders sometime after the sixteenth century. During this period, African societies valued the forest for secondary products such as fruits, nuts, fuel wood and an assortment of herbs and medicines. The main uses of timber were ornamental (carvings etc) and for canoe construction (the trunk of the cam wood tree was especially desirable for this purpose). Even traditional dwellings did not use wood. They were constructed with mud and thatch. Hence, the forest within this period was not tampered since trees could survive the traditional processes of clearing and burning.

German colonial period 1884 – 1916: The total control over land and labour allowed them to convert coastal rainforest into plantation ; by 1913 they had converted 1000sq.km of tropical forest. Agricultural products included palm products, ivory and wild rubber. In 1898 the Germans introduced the concession system for the extensive and systematic extraction of timber. The Gesellschaft Nordwest Kamerun (GNWK) maintained 5,000,000 sq ha in the north that included the northernmost parts of the Southwest. This concessions were focused mainly on plantation agriculture; rubber (Hevea), cocoa (Theobroma), oil palm (Elaies) and coffee (Coffea).

British colonial period 1916 – 1961: British ruled Cameroon through the Southern Administration area, which stretched from Lagos through Southern Cameroon and managed most of Nigeria's rainforest

and hence was responsible for the majority of the colony. Like Germans, the British equally oriented their development towards the expansion of plantation agriculture with the timber industry playing a subsidiary role. We noticed the expansion of traditional agriculture. In Southern Cameroon, Unwin A. I. estimated that there were 14,000 square miles of forest, of which 3,500 were accessible for commercial timber exploitation within this period; deforestation was attributed to shifting cultivation and not timber extraction and plantation (Macpherson, 1917).

Independence 1961 – Present: The Fako-Meme region as a dominant agrarian society which engages about 70% of the population in agriculture and agriculture-related industries is an example *par excellence* of an agricultural cornucopia or the bread basket for many of our (Central African Economic and Monetary Community) CEMAC neighbouring countries. Anthropogenic activities which stems from population growth and urbanization have exhibited far-reaching consequences on the forest landscape of this region. This can be expressed through the loss of forest lands, the destruction of watersheds, the loss of wildlife habitats, the exploitation of less suitable land, the conversion of wild lands for agriculture and urban uses, which have all contributed directly or indirectly to the further degradation of the forest environment. Most alarmingly, under the current practices, forests are experiencing the highest rates of depletion and degradation. This region has recorded significant damage to its ecosystems in the last several decades following the unsustainable use and exploitation of natural resources (Fig. 3). Therefore, since forest disappearance depends greatly on man's action, it is evident that the land use is changing. Taking into consideration the fact that the environment is our life support system which includes everything we need to support life, its state is often influenced by the behaviour of those who use it. The Fako-Meme Forest Region has a land use pattern which is relatively distinct. The land use is varied and dynamic; it changes over space and time with population increase and expanding economic exploitation. These changes are represented by the replacement of one land use type by an alternative and gainful economic activity.

The main land use in this area includes forest cover, which include the (Mount Cameroon National Park, forest reserve, community forests and mangroves), plantations and subsistence farmland, settlement with diverse economic activities, which

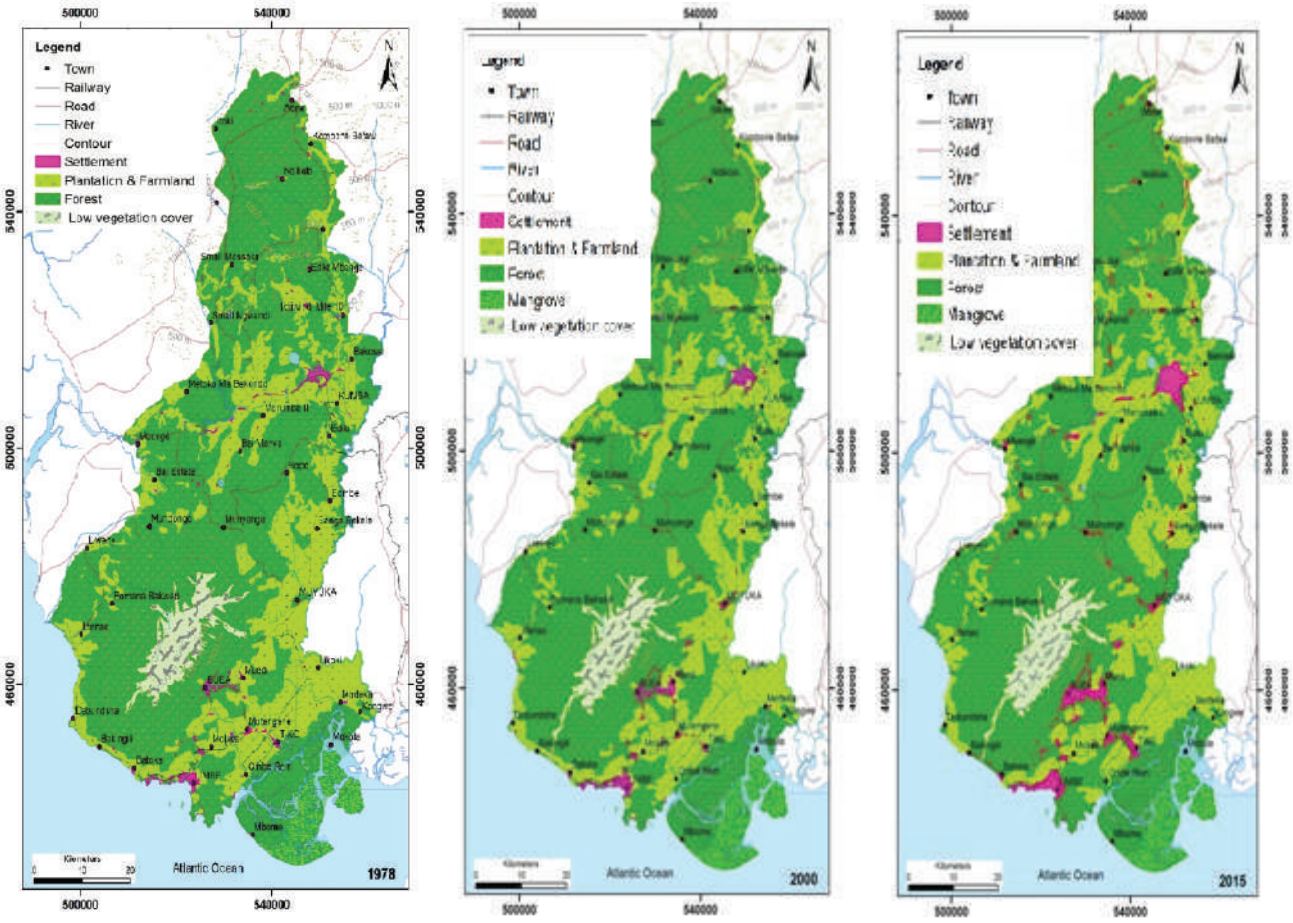

Fig. 3. Change of land-use pattern in the Fako-Meme Forest region (left 1978, middle 2000 and right 2015)

have together reshaped the land use patterns. Taking into cognisance the fact that Cameroon has witnessed a continuous process of deforestation in the last decades, the extent of forest was studied for three periods (1978, 2000 and 2015). The purpose of this assessment was to have a detailed understanding of the mutations and changing land-use pattern in the territory. The results reveals that the region's original vegetation has been altered from thick rain forest to anthropogenic vegetations such as the palm, rubber and banana plantation's of the Cameroon Development Cooperation (CDC) and the man made vegetation such as the Limbe Botanical Garden. The observed changes in the natural vegetation of this area have been as a result of man's activities such as road construction and the building of settlements and agriculture. Human activities in the Fako-Meme region of Cameroon has significantly altered the forest landscape patterns through facilitating the search for more satisfactory living conditions, which has a random but cumulative effect of altering the forest landscapes land use pattern. Surface occupation is presented in Table 1. These data illustrate the observed change in surface occupation from 1978-2000-2015.

Table 1. Fako-Meme Forest Region 1978-2000-2015

Land use types	Surface area 1978 in km²	Surface area 2000 in km²	Surface area 2015 in km²
Forest	3768.76	3213	3008.2
Settlement	34.8	101.3	201.16
Plantation & farmland	217.11	401.01	865.37
Mangrove	1122.04	912.7	414.23
Low vegetation (savanna & prairie)	57.80	302.02	712.04

The use of modern tools such as remote sensing and Geographical Information System (GIS) in the evaluation of surface dynamics is highly advantageous and the results obtained through these processes are often considered to be the most acceptable compared to any other technique (Kah et al., 2000) . The structured nature of plantations make it easy to differentiate them from non-plantation surfaces on satellite images even at lower resolutions.

Figure 4 shows that in 1978, forest occupied 3,768.76km of the territory, settlements occupied only 34.8km , the CDC plantations and farmlands around the Fako-Meme forest region of Cameroon occupied 217.11 km², mangroves occupied 1,122.04km while low vegetation (savanna and prairie) occupied 57.80 km of the territory. It is very obvious that within this period the forest was still at its primordial stage. Human activities were limited only to plantation agriculture introduced by the colonial masters. There was no population pressure on resources.

In the year 2000, we noticed a decrease in forest cover. The forest occupied 3,213 km of the territory. This decrease was caused by an increase in settlement to 101.3 km with an increase in plantation and farmland to 401.01 km². Between 1978 and 2000, plantations had more than doubled their surface area even when we do not take into considerartion the spiral effect of this, which includes surfaces transformed for farming and building by the migrants' work. Mangroves had greatly decreased to 912.7 km and equally noticeable is an increase in the area covered by low vegetation (savanna and prairie), 302.02 km.

Despite the high rate of deforestation in this area, forest still remains the major land use. Of the 5,200 km² surface area, forest occupied 3,008.2 km² in 2015. This forest comprises a mixture of the dense forest, degraded forest and areas that have been recently colonized by savanna. It should be made clear that most of this forest is concentrated in the protected areas and forest reserves. Settlement has equally been in continuous increase. In the year 2015, we noticed a drastic increase to 201.16 km². Plantations and farmland have equally been experiencing an expansion. They have more than doubled in 2015 to 865.37 km². With a surface area ≈ 5200 km² in 1978, 72% of the territory of Fako-Meme was covered by forests in (3768.76km), and in 2015 – 42%, that is less than half of the entire area. This dynamic can be considered catastrophic. If this trend continues uninterruptedly in the region, then in 60-70 years, the Fako-Meme and the slopes of Mount Cameroon will be without forest. It is easy to imagine the consequences of this.

In view of the highly dynamic humid tropical landscape arising from the intensified natural and anthropogenic modifications, the natural forest

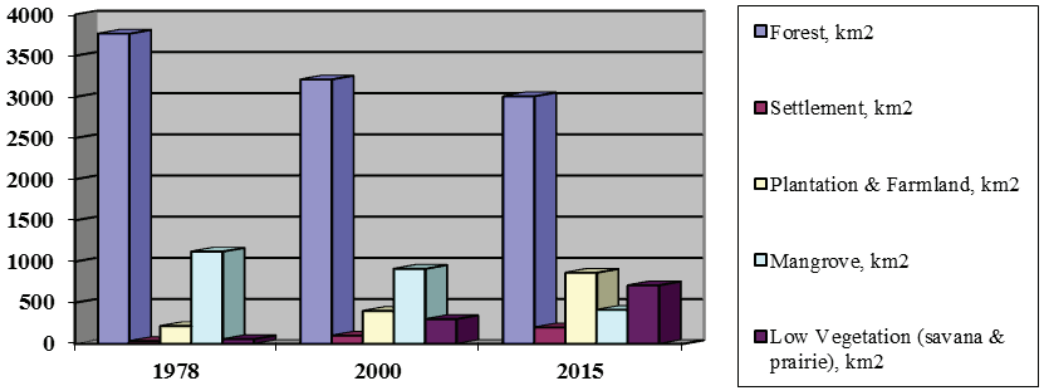

Fig. 4. Surface occupation in the Fako-Meme Forest region (1978, 2000 and 2015)

landscapes by 2015 have been swallowed or consumed by artificial landscapes, which constitute a new and monotonous cultural landscape characterized by typical agricultural landscapes. Most of these landscapes consist of western-oriented plantations in which the monoculture of selected tropical crops has been practiced. As cultural landscapes continue to swallow up the natural ones through the anthropogenic alterations introduced by man in his quest for socio-economic development for better human livelihoods, it is only very clear that the balance between existing natural and anthropogenic systems is overturned. The growing population dynamics and increase in poverty levels, due to which people cannot meet their own subsistence requirements with the means of survival at their disposal, have propelled the forest-adjacent communities of the Fako-Meme region to consider the forest as their only hope of survival . The methods and techniques of agricultural practices they use are very unfriendly to nature as shown in Figure 5.

sustainable alternative livelihood to support the needs of these vulnerable people. Some of these activities are very common in the state reserves because of the state's negligence of its duty to cater for the needs of forest-adjacent communities. With such dramatic deforestation trends, it is evident that if something is not done, the fate of forest landscapes in the Fako-Meme forest region is at stake. Urgent adaptive environmentally sustainable measures need to be put in practice. Policy makers can no longer afford to turn a blind eye to such environmental damage. Some measures have been proposed by the author, but they await implementation.

Adaptive environmental strategies for the sustainable management of forest resources in the Fako-Meme forest region. The provision of meaningful sustainable livelihoods such as pisciculture and heliciculture to replace forest exploitation activities will help to keep the forest healthy. Bee farming has, in the long term, helped

Fig. 5. Slash and Burn Method of Cultivation in the Fako-Meme

Fig. 5 shows an anarchical method of exploitation in the Fako-Meme forest region. This ravaging of the forest is provoked by an increase in the population of the forest-adjacent communities and the lack of

to reduce pressure on the forest. Yet these livelihood alternatives are declining in use and are in the process of being abandoned in the study area because of inadequate subsidization funding. If well managed,

they will become another means of livelihood thereby reducing pressure on the forest.

The formation of organized legally recognised groups (common initiative groups) will make it easier for government to finance sustainable livelihood projects. These groups will be used to sensitize entire communities to conservation strategies. Introduction of environmental education in primary schools, secondary and universities will go a long way to creating environmental awareness.

The provision of social facilities and improved living standards of the forest-adjacent communities will encourage them to collaborate with government on forest management. The use of a participatory forest management approach that integrates the forest-adjacent communities in forest management will promote sustainability. Revising the forestry policies and promulgating laws that treat forest-adjacent communities like friends and not as opponents will enhance rational management of forest resources.

To avoid encroachment and conflicts in state reserves, the boundary of the reserves should be marked with pillars planted to demarcate the border with the surrounding villages as per the German Gazette that created the reserves. The introduction of appropriate harvesting methods and techniques of non-timber forest products and medicinal plants will assure a healthy environment. The control of illegal over-exploitation of forest products, such as debarking Prunus africana, will allow the forest to regenerate itself.

Conclusion. The challenges involved in the management of natural resources in the Fako-Meme region call for responses in the form of new management models that take into account the socio-cultural and political framework and peculiarities of the forest-adjacent communities. Community participation in the decision making process of state institutions can ensure that indigenous cultural values of the rural population are taken into consideration in designing strategies for the rational management of natural resources. Involving the forest-adjacent communities in the process of decision-making offers better prospects for the development of sustainable natural resource management strategies now and in the future.

The history of forest use in the Fako-Meme forest region of Cameroon clearly reflects the influence of the colonial masters of Europe. We have identified 4 periods of geographical research. During the first pre-colonial period, the forest was still in its natural stage. Indigenous people concentrated on the cultivation of foodstuffs meant for immediate consumption. The second period of landscape history in the area was «German colonial rule», which brought the ideas of A. Humboldt and K. Ritter DOUBTFUL .CLARIFY- to local society. The European authorities strove for a reliable and continuous flow of raw materials to Germany and the creation of new economic infrastructures. This led to the creation of large agro-industrial plantations. The third period was British colonial rule of West Cameroon as a mandated territory. The British did not develop the educational system and did not conduct geographic research, but concentrated on export of raw materials to the United Kingdom. The fourth is the period of independent Cameroon .The independent government has carried out major priority efforts to preserve forests, and take care of natural resources for a very long time, but inadequate financial resources and corrupt practices have significantly slowed this development.

Anthropogenic activities, ranging from spontaneous population growth to uncontrolled urban growth, unsustainable agriculture and the spread of agro-industrial plantations and the increased use of fuelwood, have all led to a loss of biodiversity, a decrease in water flows in streams and rivers, and a decline in the quality of «green» tourism, and finally to a decrease in the provision of the population with vital resources in the challenging conditions of a steady increase in the population.

The Fako-Meme forest regions lost 42% of its forest cover between 1978-2015, as revealed by our research. This situation is catastrophic to a region with high biodiversity status. As predicted by the author, if this trend of forest loss is not halted in the coming 60-70 years, this region will be entirely deprived of its forest cover. The author therefore, calls for the implementation of urgent environmental strategies for the sustainable management of forest resources in this region.

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Horizontal and vertical zonation of the weathering rind of the northern part of the Krivy Rig Basin

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Abstract. The ferriferous-siliceous formation of the Kryvyi Rih Basin has been formed as a result of the effect of different geological processes: sedimentation, diagenesis, dynamothermal metamorphism, metasomatosis, orogenesis, hypergenesis. Hypergenic changes are manifested to a different extent within iron ore deposits of the Kryvyi Rih Basin. In the south part of the basin, thickness of the weathering rind in some places reaches 1,000-1,500 m, it is up to 2,500 in the central, and in the northern part this parameter is much lower. Hypergenic processes are observed in the sections of all stratigraphic horizons of the Saksahanska suite of the iron ore deposits of the Kryvyi Rih Basin. The thickness of their manifestations changes depending on the horizon (schist, ferriferous). Therefore, over the study, we determined the impact of stratigraphic horizon on variance of thickness of the weathering rind within the northern area of the Kryvyi Rih basin, on example of the Hannivsk deposit. The surveys were performed in all hypsometric levels of the deposit. Schematic sections of the deposit`s weathering rind were made. The products of hypergenesis are hematite quartzites with qualitative parameters (total content of iron) no lower than in magnetic quartzites. In some deposits, the reserves of the hematite quartzites are quite large, but they are not being extracted. For more detailed study of the structure of the weathering rind, manifestation of its vertical zonation was investigated, a schematic section of the weathering ring within the ferriferous-siliceous formation of the deposit was made designating all mineralogical zones. We studied the variance of mineral composition of the ferriferous rocks depending on the manifestation of horizontal zonation of the weathering rind and impact of hypergenic processes on authigenic-metamorphogenic zonation of the productivity of the deposit`s layer. We developed a scheme of mineralogical zonation of the weathering rind, therefore facilitating the enlargement of the mineral-ore base of the Hannivsk deposit and the Kryvyi Rih Basin in general for further extraction and beneficiation of hematite quartzites.

Key words: ferriferous-siliceous formation, Kryvyi Rih Basin, zonation of the weathering rind, hematite quartzites

Горизонтальна і вертикальна зональність кори вивітрювання північної частини Криворізького басейну

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Анотація. Залізисто-кремниста формація Криворізького басейну сформувалась в результатів дії різних геологічних процесів: седиментації, діагенезу, динамотермального метаморфізму, метасоматозу, тектогенезу, гіпергенезу. Гіпергенні зміни різною мірою проявлені в межах залізорудних родовищ Криворізького басейну. В південній частині басейну потужність кори вивітрювання іноді досягає 1000-1500 м, в центральній – до 2500 м, в північній частині цей показник значно менший. Гіпергенні процеси спостерігаються в розрізах усіх стратиграфічних горизонтів саксаганської світи залізорудних родовищ Криворізького басейну. Потужність їх прояву змінюється в залежності від горизонту (сланцевий, залізистий). Тому в процесі досліджень був визначений вплив стратиграфічного горизонту на варіативність потужності кори вивітрювання в межах Північного району Криворізького басейну, на прикладі Ганнівського родовища. Дослідження проводились по всіх гіпсометричних рівнях родовища. Були побудовані схематичні розрізи кори вивітрювання родовища. Продуктами гіпергенезу є гематитові кварцити, які за якісними показниками (загальний вміст заліза, якість концентрату, втрати заліза у відходах збагачення) не уступають магнетитовим кварцитам. На деяких родовищах запаси гематитових кварцитів достатньо значні, але видобуток їх не ведеться. Для більш детального вивчення будови кори вивітрювання було досліджено прояв її вертикальної зональності, побудовано схематичний розріз кори вивітрювання в межах залізито-кремнистої формації родовища з виділенням всіх мінералогічних зон. Вивчено варіативність мінерального складу залізистих порід в залежності від прояву горизонтальної зональності кори вивітрювання та впливу гіпергенних процесів на аутигенно-метаморфогенну зональність продуктивної товщі родовища.

Побудована схема мінералогічної зональності кори вивітрювання залізисто-кремнистої формації родовища. Отримані результати можуть бути основою для детального вивчення можливості розвитку мінерально-сировинної бази Ганнівського родовища і Криворізького басейну в цілому для подальшого видобутку і збагачення гематитових кварцитів.

Ключові слова: залізисто-кремниста формація, Криворізький басейн, зональність кори вивітрювання, гематитові кварцити

Introduction. The processes of weathering are manifested in the layer of ferriferous-siliceous formation of the northern part of the Kryvyi Rih Basin and within the Hannivsk deposit due to interruptions of accumulation of sediments (Bespoyasko, 2005.; Ginzburg, 1987; Dmitriev, Kravchenko, 1965). The most ancient parts of the weathering rind are Middle-Archean granites of the Prydniprovsky complex and Upper-Archean metabasites of metaclastic Konkska series.

For the ferriferous rocks of the northern part of the area, hypergenesis was the longest geological process that affected their formation. The beginning of the hypergenic process coincided with the beginning of the continental stage of existence of the Ukrainian Shield. Weathering of the ferriferous rocks is still going on, thus affecting the mineralogical transformations of metamorphogenic and metasomatically altered ferriferous quartzites and schists of the Saksahanska suite. Thus, in the faces of the quarries, weathering rind is observed, which has been forming since the Paleoproterozoic Era up to this day with an insignificant interval between the Meso-Paleogene and Meso-Neogene (Bespoyasko, 2004.; Dmitriev, Kravchenko, 1965).

The weathering rind of the deposits is represented by hematite quartzites, the total content of iron in which equals 34-35 mass percents, which, according to this parameter, is close to the magnetic quartzites. Currently, hematite quartzites are not used by the Northern Ore Mining and Processing Enterprise, though their deposits are quite large. The objective of this study has been conditioned by the necessity of increasing the coefficient of complex use of mineral mass extracted from the deposit, by developing technologies of beneficiation of the hematite quartzites. The latter cannot be done without detailed mineralogical analysis of the weathering rind, which has not been so far conducted within the productive and containing layers of the Hannivsk deposit.

Materials and methods. Structural peculiarities of the weathering rind of different geological objects are continually studied by scientists (Marszałek, 2014; Sidorova, 2015). One of the main characteristics is the depth of distribution of weathering rind . For ferriferous rocks within the Kryvyi Rih Basin, it reaches 3,000-3,500 m in some places. Its thickness changes, the main reason for this is the different tempi of epeirogenic upheavals of the blocks of the Earth's crust. Earlier, (Dodatko, Dorfman, 1973; Dmitriev,Kravchenko, 1965; Evtekhov, 2002) determined that depth of distribution of the weathering rind depends on the mineralogical composition of the ferriferous rocks, their structure, texture, intensity of the manifestation of tectonic processes. Rocks of the schist horizons differ from the rocks of the ferriferous horizons by lower fragility, higher flexibility and lower total water-penetrability (Gershoyg, 1960;Ginzburg, 1955;Dodatko, Dorfman, 1973). Therefore large thickness of the weathering rind is characteristic for ferriferous horizons.

Thickness of the weathering rind of the Hannivsk deposit in the northern area of the Kryvyi Rih Basin was measured uniformly for all hypsometric levels using geological sections. Schematic sections of the weathering rind were developed using CorelDraw 2017 software.

For mineralogical analyses, we selected 102 samples of hematite quartzites with different geological positions within the weathering rind of the Hannivsk deposit. The studies were undertaken using standard methods with serial microscopes. All analyses were performed at the laboratories of the Geology and Practical Mineralogy Department of Kryvyi Rih National University.

Results and their analysis. For detailed characteristic of hematite quartzites of Hannivsk deposit, authors of the article studied the change in the thickness of weathering rind. The measurements were performed for all hypsometric levels in the deposit. For more objective assessment of the variance of the layer thicknesses, the deposit was divided into three parts: northern, central, and southern (Fig. 1).

According to Fig. 1, thickness of the weathering rind changes from the northern to southern parts of the deposit with the following pattern: in the central part, in the zone of intense fractioning of the ferriferous rocks, due to manifestation of significant sublatitudinal rupture, its highest value is up to 138.3 m along the line of the exploration profile 27-27. Towards the northern and southern parts, thickness of the weathering rind significantly decreases, its minimal parameters were observed in the southern part of the deposit.

Also, one can also see that the thickness of weathering rind of ferriferous horizons exceeds the corresponding parameter of schist horizons, which proves a well-known pattern in the structure of the

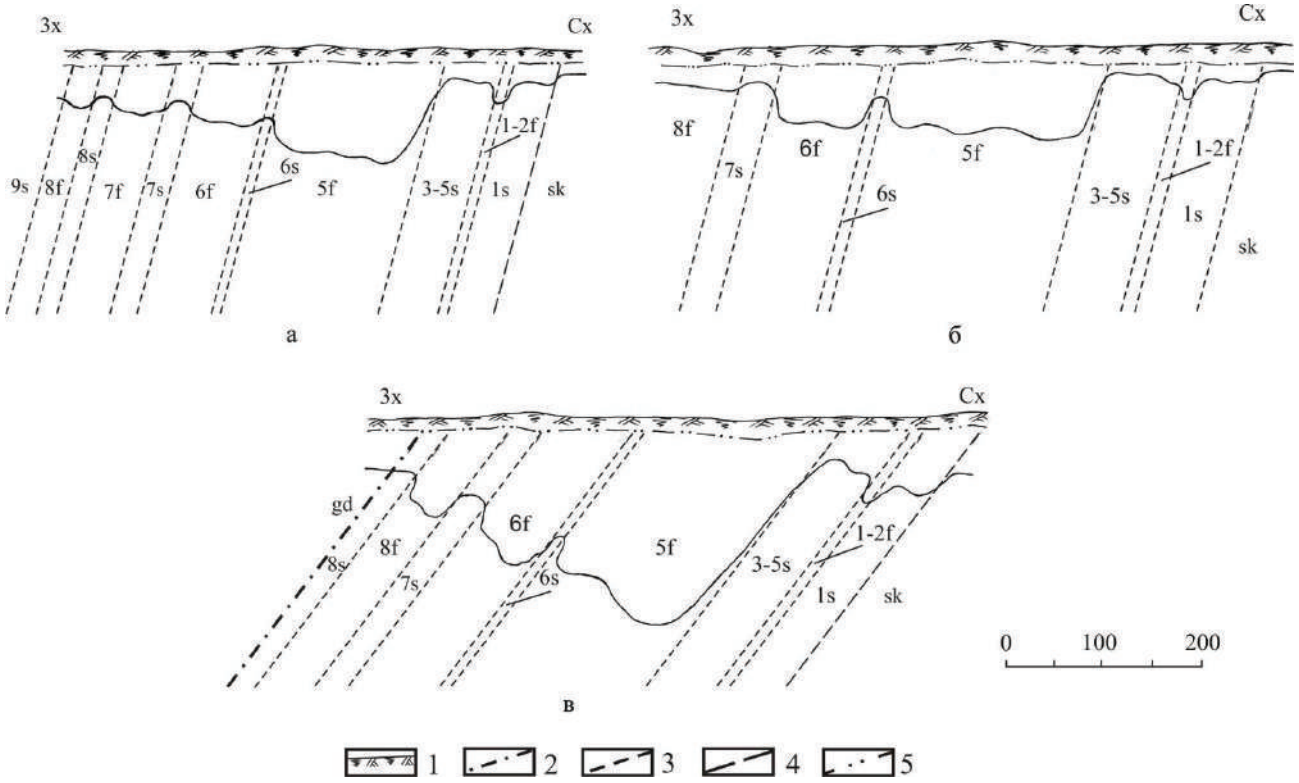

Fig. 1. Schematic sections of the weathering rind of productive and containing layers of the Hannivsk deposit.

Areas of the deposit: a – northern, b – southern; c – central.

Suites of the Kryvorizka series and stratigraphic horizons of the Saksahanska suite: Skeliuvatska suite; stratigraphic horizons of the Saksahanska suite: 1s – first schist horizon; 1-2f – fused first-second ferriferous horizons; 3-5s – fused third-fifth ferriferous horizons; 5f – fifth ferriferous; 6s – sixth schist horizon; 6f – sixth ferriferous; 7s – seventh schist; 7f – seventh ferriferous; 8s – eighth schist; gd – the Hdanivska suite;

1 – soil-vegetation layer and rocks of the Cenozoic sedimentary cover; 2 – rupture changes; 3 – lines of contacts of stratigraphic horizons; 4 – lines of contacts of the suites; 5 – line of the surface of erosive section of the rocks of the Kryvorizka series.

weathering rind of the Saksahanska suite of other iron-ore areas of the Kryvyi Rih basin. The results of determining thickness of weathering of schist and ferriferous horizons of the Saksahanska suite within the entire deposit are presented in Fig. 2.

The weathering rind of the Hannivsk deposit is characterized by horizontal and vertical mineralogical zonation . During the process of its formation, newly-formed hypergenic zones overlayed the mineralogical zones of iron-ore formation formed as a result of sedimentation, dynamothermal metamorphism (Karpenko, e. a., 2009), sodium metasomatosis (Tikhlivets, Filenko, 2017) and other geological processes.

Mineral composition of the original ferriferous quartzites (cummingtonite-, riebeckite-, biotite-containing and others) affected the pattern of hypergenic zonation, but in general for the deposit, general patterns of mineralogical orientation of the processes of hypergenesis and formation of the zonation of the weathering rind are observed.

For magnetite, is gradual replacement with martite is characteristic. The process occurs according to the pattern standard for magnetite quartzites: flexible crystals of martite at original stages of the replacement are formed along the cracks of the fractured parts of the magnetite crystals, gradually covering their entire volume (Evtekhov. e. a., 2002).

Micaceous iron oxide and quartz are resistant to hypergenic changes, as a result of which, they are present in the original rocks and products of weathering in almost the same amounts.

Hypergenic changes of silicates occur first of all due to removal of active cations (K^+, Na^+, Ca^{++}, Mg^{++}) from their crystal lattice, which causes its destruction. Out of relic chemical components of non-aluminous silicates (cummingtonite, riebeckite, aegirine, tetraferribiotite, and others) (Fe_2O_3, SiO_2, H_2O), crystal lattices of hypergenic minerals form in quartz or chalcedony, and also dispersive hematite, and at more intense weathering – goethite and dispersive goethite. If silicates of alumina are present (biotite, almandine, celadonite, stilpnomelane, etc), formation of iron hydroxides is accompanied by formation of clayey minerals, mainly kaolinite. Aluminium silicates (muscovite, cyanite, andalusite), which in notable amounts are present in schists of the first and third-fifth schist

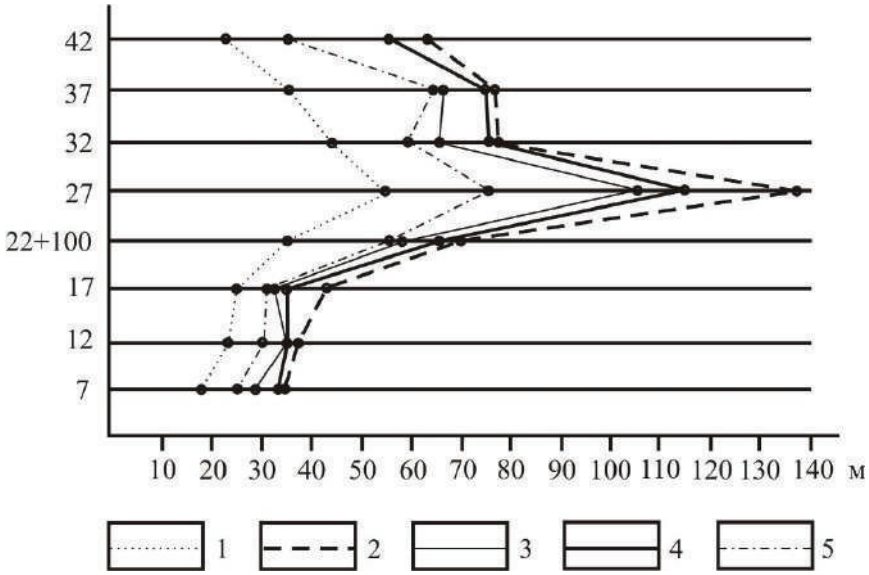

Fig. 2. Variance of thickness of the weathering rind of productive and containing layers of the Hannivsk deposit.
Stratigraphic horizons of the Saksahanska suite: 1 – third-fifth schist horizon; 2 – fifth ferriferous; 3 – sixth schist; 4 – sixth ferriferous; 5 – seventh schist.
7-42 – exploration profiles from north (profile 42) to south (profile 7).

horizons, in conditions of weathering become gradually replaced by aggregates of kaolinite, quartz, chalcedony, opal.

In insignificant amount (up to 3-3.5 vol% in total) within ferriferous rocks, carbonates are present. Their non-ferriferous types – calcite, dolomite – in the zone of intense hypergenic changes undergo complete dissolution. Iron-containing carbonates represented by sideroplesite and pistomesite, are sometimes replaced during weathering by disperse hematite, disperse goethite, and more rarely with goethite.

Gradual pattern of hypergenic replacement of metamorphogenic and metasomatic minerals causes different quantitative proportion between them and the newly formed hypergenic minerals at different hypsometric levels of productive and containing layers of the Hannivsk deposit. As a result, vertical mineralogic zonation of the weathering rind is observed.

For the **vertical section** of the weathering rind of the Hannivsk deposit, according to the content of the main ore mineral – magnetite – one can distinguish four mineralogical zones (downward by the section): goethite-martite → martite → magnetite-martite → martite-magnetite zones (Fig. 3). The latter zone has a gradual transition of pre-hypergenically unchanged magnetite quartzites. The zone of goethite-martite is the zone of maximum hypergenic changes of ferriferous rocks. It was composed of goethitised rocks of the martite zone. Contact of goethite-martite martite zone is gradual, designated by total content of iron hyperoxides (goethite, lepidocrocite and dispersive goethite), which in the content of ferriferous goethite-martite zone is higher than 5 vol%. Content of magnetite in this rock in this zone is insignificant – no higher than 2 vol%, and equals 0.47% on average. Original silicates and carbonates are absent; martite, micaceous iron oxide and quartz are partly replaced by goethite. Apart from typomorphic goethite, lepidocrocite and dispersive goethite in the rocks of the goethite-martite zone quartz, martite, micaceous iron dioxide, dispersive hematite are present as rock-forming minerals.

Ferriferous quartzites of this zone are intensely fractured, cavernous, with high number of goethite veinlets, but, despite deep hypergenic changes, original lamination is maintained.

In the sections of schist horizons, and also ferriferous quartzites adjoining to them, kaolinite is present. Broadly distributed are hematite-chalcedony, goethite-chalcedony, goethite-quartzitic jaspers, which fill the cavities in the weathered rocks.

Thickness of the zone equals around 15 m on average.

The martite zone is a zone of intense hypergenic changes. It is composed of micaceous iron dioxide-martite, martite, disperse-hematite-martite and more rarely , martite-disperse-martite quartzites. Contact of this zone and magnetite-martite is gradual. It is designated by total content of hyperoxides of iron (goethite, lepidocrocite and dispersive goethite), which in the content of ferriferous rocks of the martite zone did not exceed 5 vol%, and equals 2.37% on average. Content of magnetite is not higher than 5 vol%, equaling 1.78% on average.

The main rock-forming minerals of this zone are martite and quartz. Flooded aggregates of goethite,

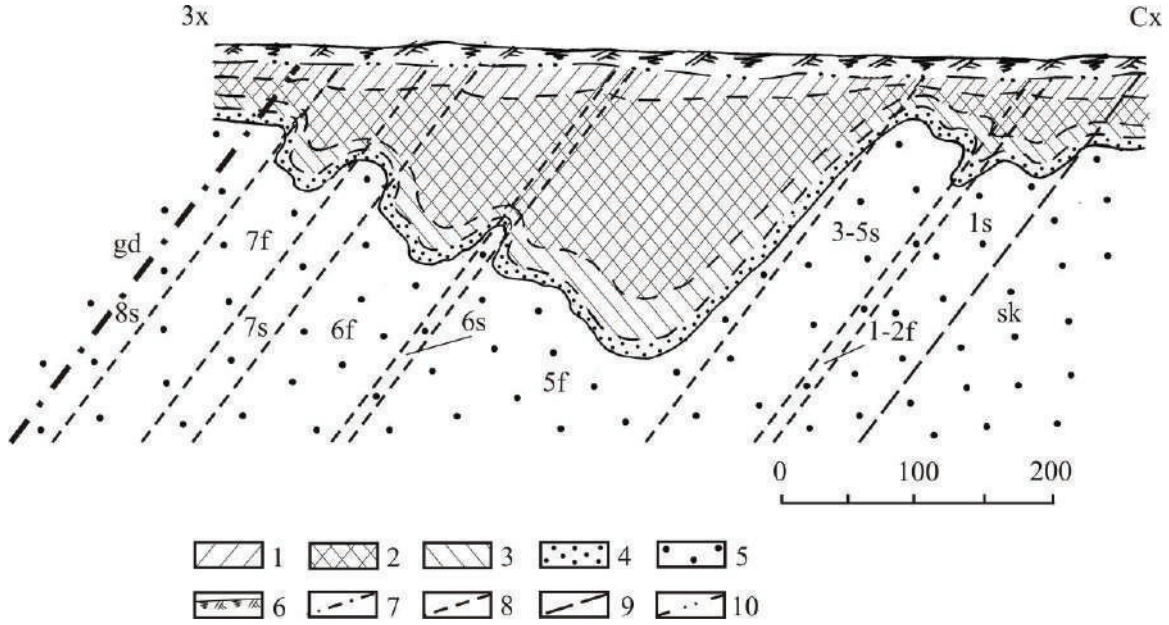

Fig. 3. Schematic geological section of the weathering rind of productive and containing layers of the Hannivsk deposits.

The suites of the Kryvorizka series and stratigraphic horizons of the Saksahanska suite: sk – Skeliuvatska suite; stratigraphic horizons of the Saksahanska suite: 1s – first schist horizon; 1-2f – fused first-second ferriferous; 3-5s – fused third-fifth ferriferous; 5f – fifth ferriferous; 6s – sixth schist; 6f – sixth ferriferous; 7s – seventh schist; 7f – seventh ferriferous; 8s – eight schist; gd – Hdanivska suite;

1-4 – zones of hypergenic changes of magnetite quartzites: 1 – goethite-martite; 2 – martite; 3 – magnetite-martite; 4 – martite-magnetite 5 – hypergenically altered ferriferous quartzites and schists; 6 – soil-vegetative layer and rocks of Cenozic sedimentary cover; 7 – ruptures; 8 – lines of contacts of stratigraphic horizons; 9 – line of contacts of the suites; 10 – line of the surface of erosive section of the rocks of the Saksahanska suite.

chalcedony, druses of quartz, calcite, dolomite and other hypergenic minerals fill the caverns and fractures, the number of which is higher within the martite zone. Texture of the rocks maintains relic lamination.

Vertical thickness of the martite zone is the largest among all the zones of the weathering rind – 40-45 m.

The magnetite-martite zone is the zone of moderate hypergenic changes of the original ferriferous quartzites. Contact with the martite-magnetite zone is gradual. Average content of the magnetite there equals 12.49%, ranges from 5 to 15 vol%. In the solution of productive tasks, this zone is called the zone of "demi-oxidized" magnetite quartzites, which become orientated towards the ore flow, because the content of magnetite in their content corresponds to the requirements to the iron ore material.

Out of newly-formed minerals, there are martite, disperse hematite, in lower amount – goethite, disperse goethite, and in rocks of pre-contact zones of ferriferous and schist horizons – kaolinite. A significant amount of half-replaced products of weathering crystals of original silicates, and also newly formed products of incomplete weathering silicates – hydromicas, beidellite, and others have been observed.

Ferriferous quartzites of this zone are characterized by heightened number of fractures, the original lamination is maintained.

The thickness of the zone ranges from 1 to 20 m, and equals 15 m on average.

The martite-magnetite zone is the zone of original hypergenic changes of original micaceous iron oxide-magnetite, magnetite, cummingtonite-magnetite, magnetite-cummingtonite quartzites.

Contact of martite-magnetide zone and zone of unchanged ferriferous quartzites is gradual, designated according to the total content of martite, the average content of which is 12.85 vol%. The average amount of magnetite is 23.06 vol%, which is by 12.77 vol% lower compared to unchanged ferriferous quartzites. According to the requirements of production, ferriferous quartzites of this zone are identified as conditional iron ore – so called "poorly-oxidized" magnetite quartzites. The dominating minerals are those of the original ferriferous rocks, intermediate products of weathering (hydromicas, beidellite) and newly-formed hypergenic silicates (mainly kaolinite) are characterized by insignificant content.

Ferriferous quartzites of this zone are insignificantly fractured, the number of veinlets of hypergenic minerals is low original lamination is entirely maintained. Thickness of the zone ranges 1 to 15 m, and equals 7 m on average.

Results of the analysis of mineral composition of rocks of the weathering rind of fifth ferriferous

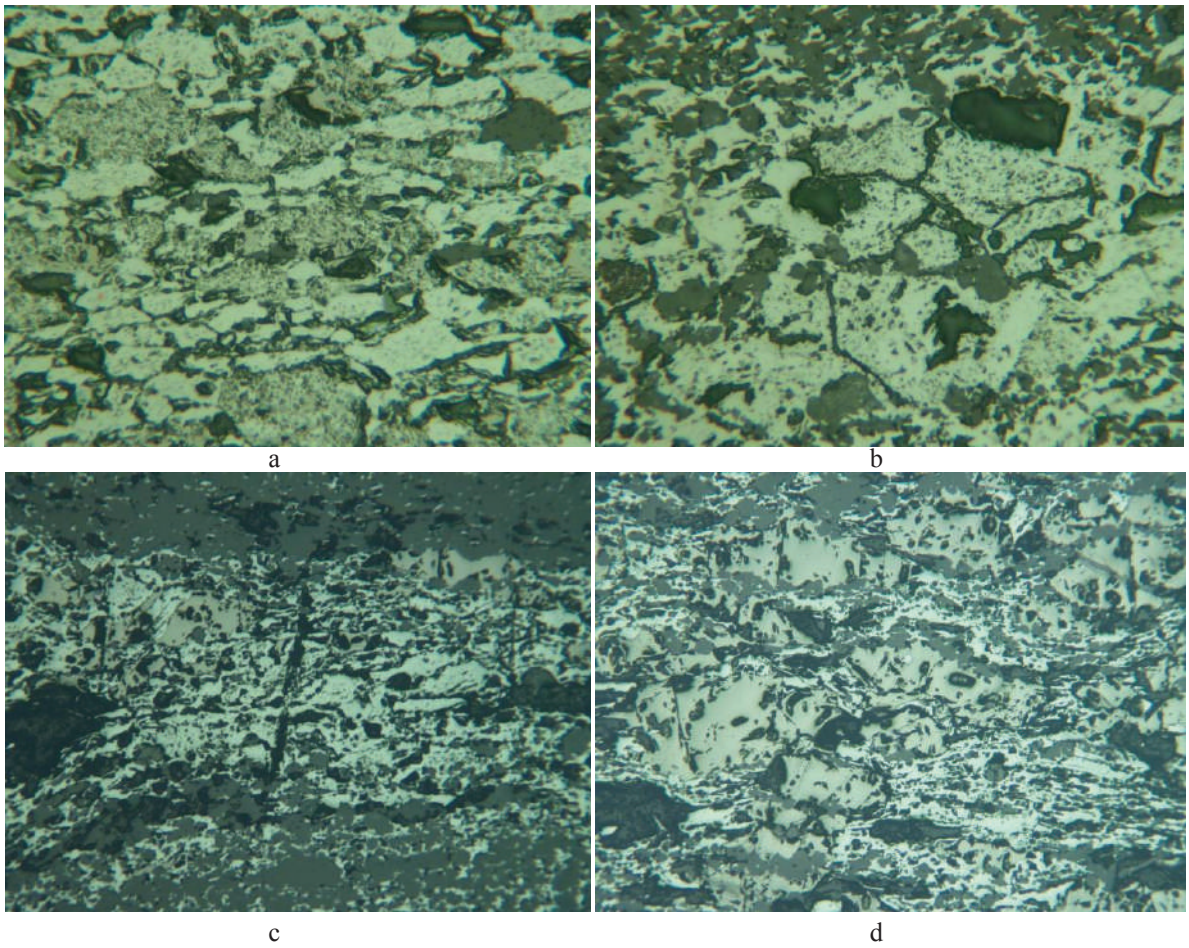

Fig. 4. Mineralogical zonation of the weathering rind of the Hannivsk deposit.
Zones: a –goethite-martite; b – martite; c – magnetite-martite; d – martite-magnetite.
Microscopic examination in reflected light. 50^{X} zoom.
a, b – light-grey – martite; dark-grey – goethite;
b, c – white – martite; light-grey – martite; dark-grey – quartz.

horizon Fig. 4 represents the mineral types of these zones of vertical zonation of the weathering rind of the productive layer. indicates that the content of the main rock-forming minerals in its section changes in the zones in relation to the intensity of manifestation of hypergenesis (Fig. 5).

Maximum content of hematite (43.30 vol% on average) is characteristic for the martite zone. Towards the original non-weathered ferriferous rocks, its content naturally decreases: to 32.70 vol% within rocks of the magnetite-martite zone, to 21.15 vol% – martite-magnetite and to 7.39 vol% within the original non-weathered ferriferous rocks. In the latter, hematite is represented by micaceous iron oxide of original micaceous iron oxide-magnetite and magnetite quartzites. In upward direction, in the section of the weathering rind – in the rocks of the goethite-martite zone – average content of hematite is lower (38.98 vol%) compared to the rocks of the martite zone due to partial replacement of hematite by iron hydoxides.

An opposite tendency was observed for distribution of magnetite in the section of horizon. In the goethite-martite zone, it is practically absent (0.47 vol%), within the martite zone its amount equals on average 1.78 vol%; within the magnetite-martite zone – 12.49 vol%; within the martite-magnetite zone it functions as a rock-forming mineral (23.06 vol%); maximum content of magnetite was observed in the original non-weathered ferriferous rocks (35.83 vol%). This is explained by the decrease in activity of hypergenic processes with depth.

The latter has conditioned the amount of quartz, which naturally increases from goethite-martite (49.72 vol%) to original non-weathered ferriferous rocks (50.79 vol%).

Maximum value of content of iron hydroxides represented by goethite, disperse goethite and lepidocrocite (8.55 vol% on average) is characteristic for the goethite-martite zone. Towards the zone of original hypergenic changes, its content reduces

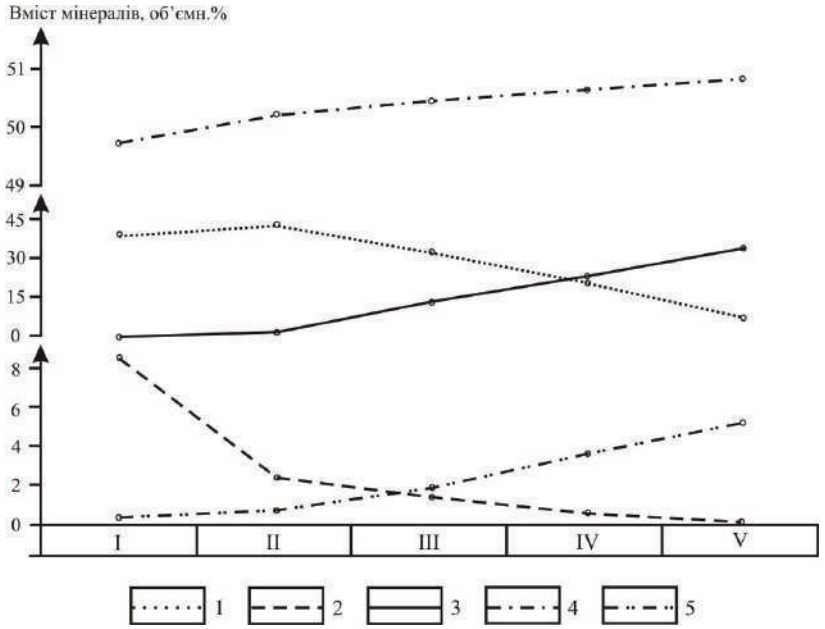

Fig. 5. Variance of content of main rock-forming minerals within hypergenically changed rocks of the fifth ferriferous horizon (according to the vertical zonation of the weathering rind).

Minerals: 1 – hematite (martite + micaceous iron oxide + disperse hematite); 2 – iron hydroxides (goethite + lepidocrocite + disperse goethite); 3 – magnetite; 4 – quartz; 5 – relic silicates (hypergenically changed cummingtonite, biotite, chlorite, ferriferous talc (minnesotaite), garnet, celadonite, stilpnomelane, albite, magnesium-riebeckite, aegerine, and others).

Zone of the weathering rind: I – goethite-martite; II – martite; III – magnetite-martite; IV – martite-magnetite; V – original non-weathered ferriferous rocks.

to 2.37 vol% in the martite zone, 1.5 vol% in the magnetite-martite zone, 0.67 vol% in the martite-magnetite zone. In the zone of original non-weathered ferriferous rocks, micaceous iron oxides are almost absent (0.1 vol%).

The opposite tendency was observed for distribution of silicates in the section of weathering rind. In the goethite-martite zone, they are practically absent (0.31 vol%), within the martite zone its amount equals 0.74 vol% on average; within the magnetite-martite zone – 1.94 vol%; within the martite-magnetite zone its amount slightly increases up to 3.86 vol%; maximum value of content of silicates was observed in the original non-weathered ferriferous rocks (5.12 vol%).

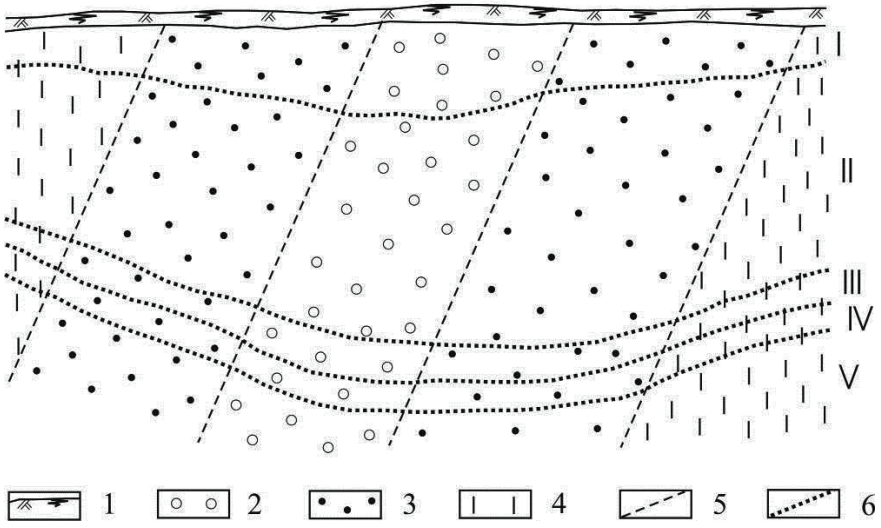

Fig. 6. Sketch of the upper part of the western face of the productive layer of the Hannivsk deposit.
1 – surface of the Earth; mineralogical types of ferriferous quartzites; 2 – micaceous iron oxide-magnetite; 3 – magnetite; cummingtonite-magnetite; 4 – borders of mineralogical types; 6 – borders of hypergenic zones: I – goethite-martite; II – martite; III – magnetite-martite; IV – martite-magnetite; V – hypergenically unchanged quartzites.

Mineralogical zonation of the weathering rind has overlain authigenic-metamorphogenic zonation of the ferriferous horizons. As a result, a complex (interferent) zonation of the productive layer of the deposit has formed (Fig. 6).

Horizontal hypergenic mineralogic zonation of the fifth, sixth ferriferous and sixth schist horizons of the Hannivsk deposit, as well as the vertical hypergenic zonation, formed under the impact of factors of weathering over a long Proterozoan-Cenozoic stage of the formation of ferriferous layer of the deposit. In the structure of the weathering rind, there are observed manifestations of horizontal zonation of the three orders. Their presence in the weathering rind of the ferriferous layer is a consequence of inheriting the zonal structure of the original geological bodies by the hypergenic formations.

Horizontal hypergenic zonation of the first order inherited the original macrozonation of the ferriferous Saksahanska suite of the deposit (Fig. 7). The central position is occupied by the macrozone of hypergenically changed rocks of the productive layer (fused layer of the fifth, sixth ferriferous and sixth schist horizons). It comprises most ferriferous types of weathered iron ores – micaceous iron oxide-martite, martite, disperse goethite-martite. In an insignificant amount, there are also martite-disperse hematite quartzites, a product of weathering of non-conditional magnetite-silicate quartzites of the sixth schist horizons and peripheral zones of the fifth and sixth ferriferous horizons.

The weathering rind of the productive layer is fringed by hypergenically changed rocks of underlying and overlying layers. The first are represented by the products of weathering of original rocks of the first, third-fifth schist and first-second ferriferous horizons – kaolinite-quartz-disperse hematite, kaolinite-quartz-disperse hematite, martite-quartz-disperse hematite schists and disperse hematite-martite, martite-disperse hematite quartzites. Weathering rind of the overlying layer is represented by hypergenically altered rocks of seventh, eighth, ninth ferriferous and seventh, eighth, ninth, tenth schist horizons – kaolinite-martite-disperse hematite, martite-kaolinite-disperse hematite quartzites.

In the sections of the weathering rinds of all stratigraphic horizons of the Saksahanska suite, horizontal hypergenic mineralogic zonation of higher (second) order is manifested, which was inherited during the weathering from their original authigenic-metamorphogenic geochemical zonation (Karpenko,EvtekhovV., EvtekhovaA., 2009). It was observed most completely in the section of productive layers.

According to generalization of the results of the mapping of the faces of the quarry, made by the author, and data of boring of the exploration wells, a topomineralogical scheme of weathering rind of the Hannivsk deposit`s productive layer has been developed (Fig. 8).

Conclusions. The obtained data demonstrate that the thickness of the weathering rind of the Hannivsk deposit of the Kryvyi Rih basin changes from the northern to southern part of the deposit with the following pattern: in the central part it has highest value; towards the northern and southern part, thickness of the weathering rind significantly decreases, reaching minimum parameters in the southern part of the deposit.

Weathering rind is characterized by manifestation of vertical and horizontal mineralogical zonation. For the former, from the surface downward, the sections were observed to contain the following mineralogical zones: goethite → martite-goethite →

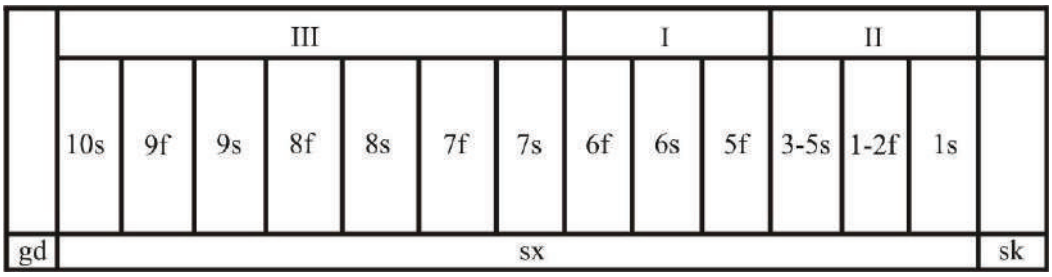

Fig. 7. Scheme of mineralogical zonation of the iron ore layer of the Hannivsk deposit.

Suites of the Kryvorizka series: gd – Hdanivska; sx – Saksahanska; sk – Skeliuvatska.

Schist horizons of the Saksahanska suite: 1s – first; 3-5s – fused third-fifth; 6s – sixth; 7s – seventh; 8s – eighth; 9s – ninth; 10s – tenth

Ferriferous horizons of the Saksahanska suite: 1-2f – fused first-second; 5f – fifth; 6f – sixth; 7f – seventh; 8f - eight; 9f – ninth.

Macrozones of the Saksahanska suite I – central (productive); II – underlying; III – overlaying.

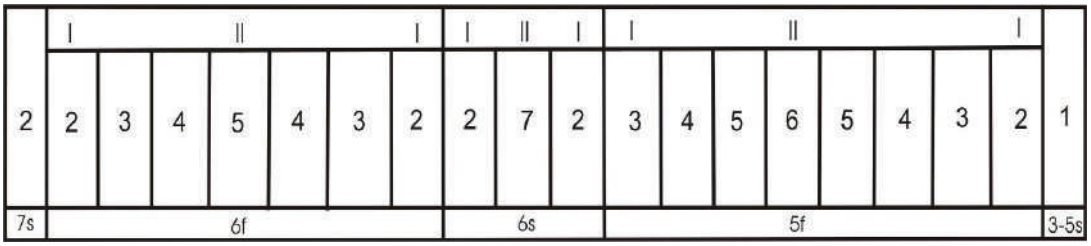

Fig. 8. Scheme of mineralogical zonation of the weathering rind of the productive layer of the Hannivsk deposit (at hypsometric level of the martite zone).

Indexes of mineralogical types of ferriferous rocks in the section: 1 – garnet-kaolinnite-quartz-disperse hematite schists; 2 – martite-disperse hematite quartzites with kaolinite; 3 – disperse hematite-martite quartzites; 4 – martite quartzites with disperse hematite; 5 – martite quartzites with micaceous iron oxide; 6 – micaceous iron oxide-martite quartzites; 7 – kaolinite-disperse hematite quartzites with martite.

Stratigraphic horizons of the Saksahanska suite: 7s – seventh schist horizon; 6f – sixth ferriferous; 6s – sixth schist; 5f – fifth ferriferous; 3-5s – third-fifth schist.

I – peripheral zones of the horizons; II – central zones of three horizons.

goethite-martite → martite → magnetite-martite → martite-magnetite → hypergenically changed magnetite quartzites.

Horizontal zonation of the weathering rinds of ferriferous horizons is inherited by their authigenic-metamorphogenic zonation. The difference is the replacement of magnetite by martite, and ferriferous silicates and carbonates – by dispersive hematite; micaceous iron oxide and quartz during weathering are relatively stable. At complete manifestation of authigenic-metamorphogenic mineralogic zonation, horizontal zonation of the weathering rind of ferriferous horizons looks as follows (from central part of the horizon towards its periphery): micaceous iron oxide quartzites → martite-micaceous iron oxide quartzites → micaceous iron oxide-martite quartzites → martite quartzites with micaceous iron oxide → martite quartzites with disperse hematite → disperse hematite-martite quartzites → martite-disperse hematite quartzites with kaolinite.

Using the results of the study, we developed schematic mineralogical sections of the weathering rind of the deposit, which were used during operative and promising planning of the mining works, development of schemes of distribution of the mineral-raw material base of the deposit, and in constant monitoring of areas of mining of ores by their mineralogical parameters.

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Features of application of information technologies in modern tourism

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Abstract. The article deals with the structure of the modern information technology system used in the tourism industry. It is emphasized that the use of information technology in each separate segment of the tourism industry, such as hotels, ticket reservations, the creation of specialized tourist products, is interlinked with all others. The purpose of the article is to reveal the peculiarities of the using of modern information technologies in the tourism industry. It was established that the introduction of information technology in the tourism industry took place in four stages, from the creation of data, through the direct development of information technologies , the development of strategic information systems and the integration of individual IT components in a network of different levels, from local to global. It is revealed that the majority of tourist enterprises use both standard and special software in their activity. For tourism enterprises to carry out marketing activities successfully, the information market offers technologies aimed at the process of automating the accumulation of survey results, planning and developing a marketing strategy. One of the most important elements in the tourism industry is computer reservation systems, which eventually integrated into global booking systems. These systems provide not only transport services, but also hotel accommodation, cruise trips, location information, bus, rail and air connections, exchange rates, weather reports, etc., allowing one to reserve all major components of the tour. Tour operators use several classic approaches to building a reservation system. The features of the market of tourist services, the specific characteristics of the services themselves and the peculiarities of their perception by consumers determine the specifics of marketing in this area. The use of information technologies, in particular the Internet, enables businesspeople and marketers to explore new market opportunities for their travel services, to highlight and explore various market segments (geographic, demographic, professional, organizational, behavioural, etc.). Tracking relevant information can be used to predict the future development of consumer demand and identify new trends in the behaviour of existing and potential customers. The use of geoinformation systems opens up broad prospects for engineering justification and design of new tourist routes and recreational areas, the publication of thematic tourist maps and the creation of web atlases, etc. Thus, thanks to information technologies, a single tourist information space is created that allows all players in the tourist market to quickly receive real information.

Key words: tourism industry, information technologies, marketing strategies, travel companies, tourist product, geoinformation systems

Особливості застосування інформаційних технологій в сучасному туризмі

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Анотація. У статті розглянуто структуру сучасної системи інформаційних технологій, що використовується в туристичній індустрії. Наголошено, що використання інформаційних технологій у кожному окремому сегменті туристичної індустрії, як то готелі, бронювання квитків, створення спеціалізованого туристичного продукту, взаємопов'язане з усіма іншими. Метою статті є розкриття особливостей застосування сучасних інформаційних технологій в індустрії туризму. Встановлено, що впровадження інформаційних технологій в туристичну індустрію відбувалося в чотири етапи - від створення даних, через безпосереднього розробку таких інформаційних технологій та інтеграцію окремих IT в мережу різних рівнів, від локальних до глобальних. Виявлено, що більшість туристичних підприємств у своїй діяльності використовують як стандартне, так і спеціальне програмне забезпечення. Одними з найважливіших в туристичній індустрії є комп'ютерні системи резервування, які з часом інтегруються в глобальні системи бронювання. Туроператори використовують кілька класичних підходів до побудови системи бронювання. Особливості ринку туристичних послуг, особливості самих послуг та їх сприйняття споживачами визначають специфіку маркетингу в цій сфері. Використання інформаційних технологій, зокрема Інтернет, дозволяє підприємцям та маркетологам вивчати нові ринкові можливості для своїх турпослуг, висвітлювати та досліджувати різні сегменти ринку (геогра-

фічний, демографічний, професійний, організаційний, поведінковий тощо). Відстеження відповідної інформації може бути використано для прогнозування майбутнього розвитку споживчого попиту і виявлення нових тенденцій у поведінці існуючих і потенційних клієнтів. Використання геоінформаційних систем відкриває широкі перспективи для інженерного обґрунтування та проектування нових туристичних маршрутів і рекреаційних зон, видання тематичних туристичних карт і створення веб-атласів тощо. Встановлено, що завдяки інформаційним технологіям єдиний туристичний інформаційний простір створений, який дозволяє всім гравцям туристичного ринку оперативно отримувати реальну інформацію.

Ключові слова: індустрія туризму, інформаційні технології, маркетингові стратегії, туристичні компанії, туристичний продукт, геоінформаційні системи

Introduction. World tourism developed extremely rapidly during the twentieth century and at the beginning of the twenty-first century. In the second half of the last century the number of inhabitants of the planet that travelled increased from 25 to 700 million people. In 2020, the world is projected to have 1.5 billion international tourists (The Travel, 2017). The UN, UNESCO and the WTO have identified the 21st century as a century of tourism.

Tourism, both international and domestic, is a sphere of growing application of information technologies (IT). The system of information technology used in tourism consists of a computer reservation system, teleconferencing systems, video systems, computers, information management systems, electronic information systems of airlines, electronic money transfer, telephone networks, mobile communications, etc. It should be noted that this technology system is not created by travel agencies, hotels or airlines, acting separately, but by all of them together. Moreover, the use of each segment of the tourism information technology system is important for all other parts. For example, a hotel's internal management systems can be linked to computerized global networks, which in turn provide the basis for communication with hotel reservation systems, which, in the opposite direction, may be available to travel agencies through their computers. So, here we are dealing with an integrated information technology system that is distributed in tourism. It becomes clear that the tourism industry is not served by computers, telephones, and video terminals as separate units – there is a system of interconnected computer and communication technologies. In addition, the individual components of the tourism industry are closely interconnected – because many tourists vertically or horizontally penetrate into each other's activities.

Considering the role of information technology in the field of regional tourism, it should be remembered that the proposed development and tourism development plans should answer the following questions: how should we assess the state of the tourism industry and the main problems of its development ?; which main areas of tourism are most in line with the interests of the region ?, where and in what is it most effective to invest money ?; how can we improve the image and increase the attractiveness of a given region for tourists ?; how can we stimulate the socio–economic development of the region through the development of tourism ?

The purpose of the article is to reveal the peculiarities of the use of modern IT in the tourism industry. According to the stated goal, the following tasks are foreseen: to outline the scope of application of information technologies in the management of subjects of tourism activity; systematize innovative approaches to the marketing activities of tourism enterprises with the use of various information technologies; to substantiate the potentially promising directions of IT implementation in the activity of tourist enterprises; to determine the state and preconditions of ensuring the quality of tourist services in the context of application of information technologies;

Material and methods of research. Analysis of recent research and publications. Research on the use of the latest information technologies in the activities of tourism enterprises and tourism in general was carried out by S.Arimov (Arimov, 2007), B. Dmytryshin (Dmytryshyn and Tytarenko 2015), V. Hudo (Hudo, 2000), T. Kupach (Kupach, 2015), S. Melnichenko (Melnichenko, 2018), N. Pinchuk (Pinchuk, Galuzyns'kyj, Orlenko, 2003), M. Skopen` (Skopen and Sukach, 2010), Pease W. R. (Pease, Rowe, Cooper, 2007), M. Meyerson, M. Scarborough (Meyerson and Scarborough, 2008). However, the research has only partly revealed the impact of information technology on the development of the tourism industry.

The development of the tourism industry contributes to reducing unemployment in the regions of Ukraine, to bringing a significant increase in revenues to local budgets, and to the improvement of territories. However, the development of tourism in the regions of Ukraine is hampered by the poor state of tourist infrastructure, lack of targeted policy and socio–economic instability. Existing problems of information provision of the tourism business on the regional level could be solved through the use of

planning and management of tourism information systems (TIS) and geographic information systems (GIS). An analysis of international experience in the creation and operation of tourist and geographic information systems shows that these systems can be regarded as a sort of statistical package – an indispensable tool in the regions' tourism business in planning, research and marketing. Thanks to information technology, the tourism product becomes more individual and flexible, and also more accessible to each consumer.

Results and their analysis. Implementation of IT in the tourism industry took place in several stages. The first step was to «create data». Its main goal was to increase the efficiency of operational activities of travel companies through automation of processes based on the use of information.

The second stage was the introduction of "information management systems" and the development of such information technologies that would increase management efficiency by improving the requirements for the organization of the transfer of information.

The third stage was the use of systems of "strategic information" that could increase the competitiveness of the firm. Different types of integrated networks were introduced to improve the direct activities of travel agencies, as well as to establish links with external organizations.

The fourth stage was the "stage of the networks", thanks to which networks were connected at all levels: local, regional, city and global. The main features of the phase – to increase the efficiency of IT, reduce the size of equipment, reduce the cost of its acquisition, increase reliability, the organization of the interconnection of terminals located in different parts of the planet. All this contributed to the fact that IT began to play an important role in the activities of all tourism organizations. As a result, all organizations, regardless of their size, the proposed product and geography, have undergone a serious process of reorganizing their business.

Today, IT technology plays a major role in the field of technical development of tourism, which is determined by a number of specific IT properties (efficiency and availability). One of the indicators for assessing the competitiveness of the country in the field of tourism is the "information communication technology readiness" (ICT). It means rapid development, involvement of a large number of organizations, companies and countries, and rethinking their concept of "provision of services" to integrate constant communication into experience (The Travel, 2017).

Today's tourism is an industry in which the collection, processing, use and transfer of information is a vital component for everyday activities. In tourism, services cannot be exhibited and considered at a point of sale like any other manufactured or consumer goods. Tourist services are usually bought in advance and away from the place of consumption. Consequently, tourism in the market is almost entirely dependent on photographs, descriptions, means of communication and information transmission.

Most tourism companies use standard software (typically Microsoft software packages: Word, Excel, PowerPoint, Outlook) as well as special software (designed to automate the solution of specific, highly specialized tourist business tasks) in their business. Not all Ukrainian tourist agents use special software, but they all use standard. The use of special software can be achieved through: separate programs or modules – "Tour Anketa", "Tour Pilot", etc.; typical software systems – "TurWin MultiPro", "Samo–Tour", "Self–travel agent", "Master–tour", etc. For the successful functioning of the market, tourism enterprises carry out marketing activities that have recently become increasingly subject to automation. In the information market there are various software products for the computerization of marketing activities, they are aimed at the process of automation of the accumulation of survey results, planning and development of a marketing strategy. The British analyst company IDL conducted a survey of European companies on the place and role of information technology in today's business. The most important, according to 64% of respondents, is the expansion of the use of IT to manage relationships with business partners (Kostenko, 2004).

The most widespread software products among domestic tourism actors, according to the results of the Internet poll, are: TurWin MultiPro, Samo–Tour, Self–Travel Agent, Master–Tour, Tour–client, Tour–Manager LIGHT, Parus Travel Agency, Parus Hotel, Parus Restaurant, BS Integrator, Epitome Enterprise Solutions, OPERA Enterprise Solution, Hotel 3 and more. The given automation systems allow users to organize administrative processes and conditions of operational activity at the enterprise by combining the existing operations and individual application packages into a single integrated process. In practice, tourism enterprises can implement and gradually automate certain functional groups of processes. The specifics of the manufacturing processes of tourist enterprises consists in designing routes and tours.

IT in modern tourism is a communication centre that embraces various producers within the tourism industry. It is the information, and not the

goods, that provide a link between the producers of tourist services. This information is about the availability, cost and quality of these services. Real payments are not transferred from travel companies to suppliers, and commissions – from tour suppliers to tour companies, only information on payments and receipts is transmitted.

There is a system of interconnected communication and computer technologies in the tourism industry. All this makes it possible to consider tourism as a highly integrated service (Titarenko, Makarova, Dajntbegov, 2000).

Ability to work with information, collect, process and make the only correct decision on it, developing information standards today is the basis for successful organization of tourism business. The importance of IT in tourism is also determined by the fact that it provides multiple productivity growth in the service sector.

Today, the most important information systems in the travel industry are computer reservation systems. In the last decade, due to the increasing use of computer reservation systems, they received a new name – Global Distribution System, (GDS).

The basis of modern computer reservation systems was laid in the 1950s. Due to the growing popularity of air travel, there was a need for the creation of global reservation centres by airlines, the task of which was manual processing of airline ticket reservations received by mail, telephone and telegraph from tourist organizations and end- use customers.

Despite the large size and the large number of staff, the reservation centers could not cope with the growing volume of information. This served as an impetus for the development of computer reservation systems for major airlines.

The reservation systems provide not only transport services, but also accommodation in hotels, cruise trips, location information, bus, rail and air connections, exchange rates, weather reports, etc., which allows users to reserve all major components of the tour.

The reservation systems are a common IP that provides the most important distribution networks for the entire travel industry. Due to the existing databases, travel agencies have access to information on available services, cost, quality, arrival time and departure for a number of tourist services from tour providers. Today, the largest computer reservation systems in the international tourism market are the Sabre, Amadeus, Worldspan and Galileo systems. Together, these systems account for approximately 500 thousand terminals installed in hotels around the world, accounting for more than 90% of the market. Another 10% is occupied by regional reservation systems, or those that are in the merger with one of the above. Each element of the GDS though is global, but has its distribution range. Thus, Amadeus and Galileo are distributed in Europe, Saber and Worldspan – in America (Dmytryshyn and Tytarenko, 2015).

Currently, there is a large variety of reservation systems for tour operators and several typical approaches to building a booking system for a tour operator company (Pease, Rowe, Cooper, 2007, Mel'nychenko, 2008, Gljebova, 2016). They can be classified in this way.

1. *Classic variant*: step–by–step booking option. Reservation of a tour or a separate service is carried out step by step, for example, the first step is the choice of a country, the second – the choice of the resort (direction), the third – the choice of the intended date of arrival, etc. Although the tourism industry was changed two decades ago with the Internet, today there is a second revolution in the tourism industry, with the rapid growth of services provided through mobile devices. In less than two years, the proportion of online booking has grown rapidly from 9% to almost 33% (The Travel, 2017).

2. *Booking through the order basket:* the travel agent works with price lists. By creating a different order basket (it may be travel packages and individual services or service packages), these services can be booked.

3. *Reservation through a dynamic price list*: with the help of a set of filters, you can select the tourism product that is needed, called the booking option this is very popular for mass destinations.

4. *Reservation of the tour through selection (search) of the optimum pric*e, or selection of a special offer, or hotel selection, etc. With this booking option, it is convenient to conduct a selection of tours based on a set of search criteria, such as the name of the resort, the hotel's «star», hotel service, food, the estimated range of prices, etc.

5. *Reservations of cruises*. In order to properly select and book a cruise, a potential buyer should receive a large amount of information – a description of the cruise company, the cruise ship itself, its scheduling, cabin prices, cabins, etc.

6. *Booking of bus tours*. Bus tours also have specifics. As a rule, this involves tours with complex routes in many cities and countries. In the booking of bus tours it is necessary to show the exact route of movement and real loading of the vehicle.

7. *Reservation of sanatorium and spa treatment facilities*. In such systems, the main thing is to carry out a qualified selection of a sanatorium based on the medical indications and benefits of the patient.

For proper selection of sanatorium and rehabilitation facilities, it is necessary to indicate the list of medical conditions and some specific data about the patient (possible treatment time, place of residence, recommended climate, etc.). To enable the client/ patient to make an informed selection, a large amount of medical information about the sanatorium is provided.

Today, tourism business management software allows you to solve various tasks. Travel companies that are seriously operating in the market of tourist services will not be able to significantly increase their productivity if they ignore the latest software in the management of tourism activities. Conditionally, they can be divided into six sections: customer service, tours, directory support, payment management, preparation of outgoing documents, service regimes.

The section "Tours" gives you the opportunity to independently create tourist programs (transport, accommodation, additional services) for travel agencies or to enter the database of ready–made tourist products. The client part of the program provides an opportunity to organize a database of tourists, to accept orders and calculate the tour price, taking into account existing discounts. The accounting section of the program allows you to automatically generate all types of reports and payment documents (expense and profit cash orders, invoices, etc.). The software package also provides reliable work on the local network, compatibility and organic use with the programs of other developers. An integral part of any computer agent program are reference databases.

These software packages provide functional capabilities that allow one to quickly and efficiently manage the travel agency, responding to the rapid changes in demand and supply, and allow the best results to be achieved in a short time.

Without the Internet it is impossible to imagine the activities of travel agencies. The Internet is used in virtually all major business processes within the travel agency, from the search and attraction of customers, as a communication and marketing tool, to the formation of tourist products .It provides a large amount of information needed by travel agencies ,from the addresses of hotels and schedules of flights to visa and customs rules , and offers from domestic and foreign tour providers, and information unlimited in scope – ranging from price lists to entire catalogues. Information on the Internet is available to users, agencies or clients 24 hours a day and 7 days a week. The use of the Internet in the field of tourism includes many other areas.

1. Obtaining access to the use of modern communication systems, including e–mail, digital telephony, etc., which significantly reduces the cost to tourism enterprises for negotiation, business correspondence, etc.

2. Possibility of creation and successful application of internal–corporate systems for booking their tours through the Internet. Travel agencies from the tour database, located on the Internet, choose one of the offers, enter their details and data on tourists who are entered in the internal base of the tour operator. The system automatically in real time recalculates changes in prices for package tours, takes into account non–standard placements, requirements and other functions. In this case, the agency in real time can trace the stages of passing the order, estimate loading of hotels, flights, etc.

3. Obtaining different reference data, including countries, tariffs, prices, weather forecasts in different parts of the world and others in real time, which contributes to the formation of a qualitative product tour.

4. Getting access to global reservation systems.

5. Ability to create new marketing channels for the promotion of tourism services, in particular, the creation by firms of their own websites , which will allow users to easily find information on conditions at resorts, prices, services provided, more detailed information about the organization of the tour; feedback pages for tourists, forums (online conferences), virtual tourist offices, e–commerce, etc.

6. Implementation of online multimedia technologies, in particular directories and catalogues. Multimedia is an interactive technology that provides work with video, animation, text and soundtrack. Tourist guides and catalogues are currently available online. Electronic catalogues allow you to travel virtually on the proposed routes, view these routes in active mode, get information about the country, objects of interest along the route, hotels, camp sites, motels and other accommodation facilities, get acquainted with the system of benefits and discounts. In addition, these directories usually offer information on the rules of registration of tourist documents, tourist formalities, models of tourist behaviour in extreme situations, etc. The client can plan the programme of the tour itself, choose it according to the given optimal parameters (price, system of privileges, system of transport, season, etc.). When using multimedia technologies, a potential customer is promptly provided with information about any tour of interest to him/her and this allows him to quickly and accurately select the relevant tourist product. Multimedia technologies are effectively used in the field of advertising, PROMO and PR–technologies.

7. The rapid development of the Internet also

affects the attitude of travel agencies to advertising. For example, some travel agencies have begun to reduce the volume of published newspaper ads, preferring to place their own ads on the Internet. Big advertisements in newspapers are now being squeezed out by small ones, with the address of the information page of the company on the Internet. The Internet allows mass advertising campaigns at a minimal cost. If you place commercial information in a popular electronic edition, it will be available to people around the world for a long time. For a small fee on the Internet you can publish detailed information about the company, its products and services, terms of working with customers, etc.

The specifics of tourist services today is that they, as a rule, do not acquire a real form. Accordingly, the following conclusions should be made: the service does not exist until it is provided, that is, the product is created during the provision of the service. As a result, it is impossible to compare two different vendors offering identical services before receiving them. Often the provision of tourist services requires special knowledge and skills, which are difficult for the buyer not only to evaluate, but sometimes to understand . Therefore, tourists often seek to work with one seller (Kotler, Boujen, Mejkenz, 2012).

The features of the market of tourist services, the specific characteristics of the services themselves and the peculiarities of their perception by consumers determine the specifics of marketing in this area. The main task of marketing is to help the client to evaluate the company and its services. All tourist services, from transport to intermediary, constitute a tourist product. Thus, the tourist product represents any service that satisfies those or other needs of tourists willing to pay for it.

Along with the general indicators, the tourist product has a number of distinctive features:

– it is a complex of services and goods (tangible and intangible components) which is determined by a complex system of relationships between different elements;

– the demand for tourist services is extremely elastic in relation to the level of incomes and prices, but mainly depends on social conditions;

– the client, as a rule, cannot see the tourist product prior to its consumption, and in itself consumption is mainly carried out directly at the place of production of tourist services;

– the client crosses the distance that separates him/her from the product and place of consumption, and not vice versa, and also depends on indicators such as space and time;

– the offer of tourist services differs in its inflexible production, they can be consumed only directly on the spot. The hotel, airport, recreation centre cannot be moved at the end of the season to another region. Travel services cannot adapt in time to changing demand;

– a tourist product is created by the efforts of many firms, each of which has its own working methods, specific needs and various commercial goals;

– the high quality of tourist services cannot be achieved in the presence of even insignificant shortcomings, since tourist service consists of these very small details;

– the assessment of the quality of tourist services is characterized by considerable subjectivity;

– significant influence on the consumer's assessment is made by people who are not directly related to the package of services purchased (for example, locals, members of the tourist group);

– the quality of travel services is influenced by external factors which count as force majeure (natural conditions, weather, tourism policy, international events, etc.).

These specific features of the tourism product have a significant impact on marketing in tourism and its information component (Pinchuk, Galuzyns'kyj, Orlenko, 2003). Tourist marketing is defined as the identification of the most complete satisfaction of people's demand from the point of view of social and psychological factors, as well as the identification of the financially most rational way of dealing with travel agencies, which allows one to take into account the identified and hidden needs in tourist services (Meyerson and Scarborough, 2008, Mazaraki, Tkachenko, Mel'nychenko, 2013).

The use of IT, in particular the Internet, enables businesspeople and marketers to explore new market opportunities for their travel services, to highlight and explore various market segments (geographic, demographic, professional, organizational, behavioural, etc.). Tracking relevant information can be used to predict the future development of consumer demand and identify new trends in the behaviour of existing and potential customers.

The main feature of the e–commerce market is its interactivity. The manufacturer can at any time find out the user's opinion about the consumable product or service, process the received information and make a decision. This allows the manufacturer to flexibly change its own marketing policy, depending on the circumstances (for example, fluctuations in demand) (Ponomarenko, 2002).

The Internet opens up to travel agencies not

only the ability to effectively organize feedback and to quickly investigate current demand, but also flexibly change marketing plans depending on the circumstances. The Internet under present conditions has become an independent tool for finding fresh marketing information that far exceeds the usual media. In addition, the use of the Internet greatly reduces overheads on the promotion of goods and services while reducing the risk of investment.

Internet marketing interacts with a set of subsidiary industries that include not only banner advertising and public relations, but also study the demand of the consumer audience, the development of algorithms for the formation of high–efficiency advertising campaigns, the means of correct positioning of the trademark in the market, the technology of electronic commerce. This allows Internet marketing to rapidly evolve and influence the development of the tourist industry (Gljebova, 2016, Meyerson and Scarborough, 2008).

If the company is sufficiently diversified, then it will be able to penetrate into new business spheres with the help of the Internet before others, instead of trying to compete within their current business.

A growing role in effective promotion of tourist products on the market of tourist services is played by geographic information systems. Application of geoinformation systems and technologies means the transition to a new, more qualitative level of management, planning, design and operation of complex tourism industry systems. Therefore, the introduction of GIS in the tourism sector is a topical issue of the entire territory of Ukraine. The legal basis for this is the Law of Ukraine "On the National Program of Informatization" of 04.02.1998, by which geoinformation systems are classified as the main category in the implementation of the programs of informatization of Ukraine (Zakon, 1998). GIS is defined as an automated information system designed to process spatio–temporal data, the basis of which integrates geographic information (Vysochan, 2011). Thus, GIS is defined as an organized set of certain complexity of equipment, software, specially created geographic data and personnel, forming a special complex, intended for the effective input, storage, updating, processing, analysis, and visualization of all types of geographically oriented information. The entire variety of GIS functions can be grouped into categories, among which the most significant are the following: data collection and input; their correction and storage; restructuring, generalization, transformation; request, analysis (calculation); presentation of results.

Using GIS, the following functions are carried out:

– creation of a universal basis (geographic database) for the organization of various types of information necessary for the study of the situation, for research or for management in a particular region;

– a tool for displaying the dynamics or for predicting the functioning of complex natural and man–made phenomena and as a reference and information system;

– GIS is an important tool in modeling or for the creation and use of knowledge bases and expert systems.

Structurally, GIS is a complex, organized system that includes the following components:

1) data management (in the project it is important to determine the general organization of the system, provide the necessary staffing, choose the nature of administration);

2) data collection (determining moment – types of data sources and their exchange formats);

3) entering and storing data (it is necessary to find the most accessible ways of transferring all data into a digital form);

4) search and analysis of data (enough to perform standard model–analytical operations);

5) using (creation of the user interface);

6) information output (mathematical and cartographic modeling and generation of maps in the given form).

To work in the tourism business you need to have information about:

– natural conditions for the organization of specialized types of tourism and recreational activities;

– excursion potential of cities and administrative districts;

– features of the hotel industry, transport and other tourism infrastructure;

– provision of tourism personnel;

– opportunities, problems and conditions for provision of basic and additional services in the field of hospitality.

It should be noted that specific indicators are determined by the peculiarities of the recreational resources of the territory.

From the list it becomes clear that even the minimum necessary set for creating the optimal combination of goods for the implementation of tourism or the process of providing optimal forms of targeted services and services in the organization of recreation will not be successfully completed without GIS projects.

In the field of tourism, recreational activities and

hospitality industry it is expedient to develop GIS projects for solving the following tasks:

1) inventorising of natural and socio–economic resources and assessment of their degree of use in tourism and recreation;

2) monitoring of the state of the environment (biotic components) and revealing the scale (reasons) of its transformation as a result of recreational activity and tourism;

3) development of strategic programmes and specific plans for managing resources, objects, territories in the short and long term;

4) information support for regional sustainable development projects.

The advantage of GIS is determined by the visual representation of hundreds and thousands of digits, dozens of geographical names, easy access and basic topographical and socio–economic information in understandable images. With the help of GIS, it is possible to introduce geographic analysis functions in the process of development of prospective tours and organization of recreational zones with the service of a wide range of requests – from the calculation of time and the offer of optimal segments of a tourist trip to the preparation of a seasonal route sheet and the schedule of an agreed order and the use of charter flights from different companies and states (Mihjejev, Noskova, Chudakolov, Ju., 2015).

The use of GIS allows us to rationally justify the choice of the necessary information technologies and their competent use in the work of any tour company, which can significantly increase competitiveness, reduce the complexity of routine work, accelerate the processes of obtaining and providing information necessary both when working with partners and customers, as well as when making managerial decisions.

Thus, the use of the Internet provides the formation of a single tourist information space in which all players in the tourist market (tour operators, travel agencies, clients) have the opportunity to place or select the necessary information in real time, with the essential factors being «clarity» and «truth» This information is for everyone, that is, all information should be treated equally. Information should reflect the real state of affairs.

Conclusions. Information technology creates a single tourist information space, which enables clients to create their own tours without the participation of travel companies, significantly saving their financial resources. On the basis of the above, we can conclude that with the increase in the volumes, quality and diversity of digital spatial information, the role of geoinformation systems and technologies as the main tool for visualization, search and analysis of information when making various management decisions will increase. The high degree of development and application of IT makes it possible to effectively organize not only the work of tourist organizations, but also to carry out its certification.

Automation of the information management process helps to ensure a qualitatively new approach to management decisions. Thus, in the current market conditions, with the increase in the volume of tourism receipts and increasing competition, the subjects of tourism activity depend on effective management, which is impossible without the use of modern IT, providing a quick response to customer needs and maximum satisfaction, in accordance with the requirements of enterprise flexibility, orderliness and consistency of operations.

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Potential territorial risk in eastern Ukraine

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Abstract. The research presented here is focused on assessment of potential territorial risk in the East part of Ukraine, where the military conflict has been going on for five years. Such kind of risk can be classed as a complex risk level of hazardous facilities or territories. This study determines the boundaries of territorial risk distribution with defined levels of danger. The practical implementation is reflected in the web-based geographic information system (web-GIS) for displaying environmental information in Donetsk and Luhansk regions in real time. The research defines an opportunity for further practical application of this development considering the military conflict in the Donbas. The Donbas Environmental Information System (DEIS) is an interactive map of Donetsk and Luhansk Regions. It was developed within the framework of the Project "Environmental Assessment and Recovery Priorities for Eastern Ukraine" by the OSCE Project Co-ordinator in Ukraine upon the request of the Ministry of Ecology and Natural Resources of Ukraine. The supporting of the system is carried out by the State Ecological Academy of Postgraduate Education and Management (DEA) of the Ministry of Ecology and Natural Resources of Ukraine, in particular the Center for Environmental and Resource Restoration of the Donbas within the framework of the Project of the OSCE Project Co-ordinator in Ukraine "Assisting the Ministry of Ecology and Natural Resources of Ukraine in improving environmental monitoring mechanisms".The main task of this study is to implement the software for collecting, processing and visualization of the information about the environment and factors that may affect it. This will make it possible to increase the effectiveness of environmental management in order to meet the environmental safety requirements in Donetsk and Luhansk regions.

Keywords: environmental safety, geoinformation system, Donbas Environmental Information System, environment, military conflict, OSCE, environmental monitoring

Потенційний територіальний ризик на сході України

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Анотація. Дослідження зосереджено на оцінці потенційного територіального ризику у східній частині України, де військовий конфлікт триває вже п'ять років. Такий вид ризику може служити комплексом рівня ризику небезпечних об'єктів або територій. Дослідження визначає межі поширення територіального ризику з певними рівнями небезпеки. Розроблено веб-орієнтовану геоінформаційну систему (веб-ГІС) для відображення екологічної інформації стосовно Донецької та Луганської областей в реальному часі з урахуванням збройного конфлікту. Здійснено експериментальні дослідження її роботи у сфері тестування програмного забезпечення. Відзначено перспективи подальшого практичного застосування даної розробки з урахуванням військового конфлікту на Донбасі, великий внесок у забруднення техноекосистеми може вносити як підприємства, так і продукти згоряння після бойових дій. Інформаційна система довкілля Донбасу (DEIS) –це інтерактивна карта Донецької та Луганської областей. Вона розроблена в рамках проекту «Оцінка шкоди, завданої довкіллю на сході України» на замовлення Міністерства екології та природних ресурсів України Координатором проектів ОБСЄ в Україні. Подальше наповнення та розвиток системи здійснюється в рамках проекту Координатора проектів ОБСЄ в Україні «Допомога Міністерству екології та природних ресурсів України в удосконаленні механізмів моніторингу довкілля» Державною екологічною академією післядипломної освіти та управління (ДЕА) Мінприроди, зокрема Центром еколого-ресурсного відновлення Донбасу. Основним завданням є впровадження в практику природоохоронної діяльності органів державної влади програмного забезпечення щодо збору, накопичення, обробки та представлення інформації про стан довкілля та чинники, які можуть на нього вплинути для підвищення ефективності управління природоохоронною діяльністю та додержання вимог екологічної безпеки у Донецькій та Луганській областях.

Ключові слова: екологічна безпека, геоінформаційна система, інформаційна система довкілля Донбасу, навколишнє середовище, військовий конфлікт, ОБСЄ, моніторинг довкілля, відновлення Донбасу, техноекосистема

Problem statement. Currently the functioning of the state environment monitoring system in Ukraine is substantially ineffective. There are many scientific publications focusing on a certain approach aimed at modernizing the existing environmental monitoring system,which can be applied for the coal enterprises of Ukraine, and in particular for the Donbas . On the other hand, they are too conceptual or merely related to the engineering component of the problem, such as the development of software and hardware measuring equipment. The aformenetioned conditions require a fundamentally new approach towards to improving the information technology system and its structure for further obtaining, processing and visualization of the data about the quality of the environment.

Identification of the remaining challenges. Currently, is it especially relevant to implement the environmental information systems and software products using the geoinformation technologies and web-technologies to take prompt decisions on monitoring tasks. Web GIS is a geographic information system which is based on web technologies and enables one to combine the individual components of environmental features in on-line maps. Web-based GIS services provide access to spatial data, processing, analysis, search and visualization. In particular, the mapping services allow maps to be displayed; geo-processing services make it possible to simulate the spatial relationships between features and analyse them. Considering the functionality, it can be concluded that web GIS is almost equal to the desktop GIS systems: the ultimate users have the tools enabling them to add, edit, analyze and search information, use various maps, assign geographic coordinates of features, etc. To use web-based GIS, it is not necessary to have any specialized software or specific qualification - just a web browser (Firefox, Google Chrome, Safari, etc) and a stable Internet connection.

While exploring the pollution level of the Donbas the main interest was focused not on the pollution of a city or district but on the research on each single pollution source, which are not obtainable from the government agencies involved in the environmental monitoring system. Currently, taking into account the military conflict in the Donbass, a huge contribution to the pollution of the techno-ecosystem can be made both by industrial enterprises and combustion products resulting from combat operations.

The Donbas Environmental Information System (DEIS) is an interactive map of Donetsk and Luhansk Regions. It was developed within the framework of the Project "Environmental Assessment and Recovery Priorities for Eastern Ukraine" (2017) by the OSCE Project Co-ordinator in Ukraine upon the request of the Ministry of Ecology and Natural Resources of Ukraine. The supporting of the system is carried out by the State Ecological Academy of Postgraduate Education and Management (DEA) of the Ministry of Ecology and Natural Resources of Ukraine, in particular the Center for Environmental and Resource Restoration of the Donbas within the framework of the Project of the OSCE Project Co-ordinator in Ukraine "Assisting the Ministry of Ecology and Natural Resources of Ukraine in improving environmental monitoring mechanisms" (2018-19).

Scientific objective of the paper: The paper is aimed at researching and discovering the potential territorial level of risk in the East part of Ukraine, in particular in Donetsk and Luhansk regions, where combat activities are taking place. The objective is achieved through the analysis, comparison, combination, and prioritization of various factors which might have an effect.

Practical objective of the paper: To develop and implement software allowing collecting, processing and visualization of the information about the environment and the factors that may affect it. This will help increase the effectiveness of environmental management and as a result help to meet the environmental safety requirements.

Methodology section of the paper. The complex risk measure characterizing a dangerous facility or territory (in our paper it is the East part of Ukraine) is a potential territorial risk – the spatial probability distribution (or frequency) of the negative impact of a certain level.

In the works (Lysychenko G.V., 2008, Kachinskiy A.B., 2001; Rudko G., 2016, Bilyavsky G.2006, Shmandiy V.M., 2013) territorial risk is defined as "the probability of dying of a person who is located in a given place of space from potential sources of danger."It is assumed that the conditional probability of the object of impact in a given place of space is equal to 1 (a person is at a certain point of space throughout the period of time under consideration).

The potential territorial risk determines the potential of the maximum possible risk for specific objects of impact, located at a certain point of space. The potential territorial risk can vary in a wide range. We consider potential territorial risk as an intermediate level of danger, which will be used to assess the individual and/or social risk of technogenic emergencies in the future.

In the simulation of hazardous man-made processes for assessing the risk associated with the release of hazardous substances, the potential territorial risk at a given point (x, y) is determined by the formula:

$$R_T(x,y) = \sum_{ij} P_i(A) P_{ij}(x,y) P_j(L),$$

where $R_T(x, y)$ – potential territorial risk; $P_i(A)$ – probability of an accident in scenarios i; $P_{ij}(x, y)$ – probability of realization of j-th mechanism of impact at point (x, y) for the accident script i; $P_j(L)$ – the probability of case of dying (or disease) from realization of the mechanism of impact j.

In practice, as a rule we often know the distribution of potential territorial risk for individual sources of danger and for individual accident scripts.In this case, the probability of an event initiating an accident is often assumed to be equal to 1. Consequently, the potential territorial risk is defined by the probability (or frequency) of the negative result of implementing the mechanism of impact at the point of the territory where the emergency occurred (Fig. 1 - Donetsk and Luhansk regions, located in the East of Ukraine).

Within the framework of cooperation, the Ministry of Environment and Natural Resources of Ukraine, the OSCE Project Coordinator in Ukraine, and the State Ecological Academy of Postgraduate Education and Management are focused on providing the accuracy and completeness of information. However, they are not responsible for the reliability of data, which were obtained from open sources. Informational messages obtained from such unofficial sources can be used for analysis and for further research (Shapar A.H., 2015; Bondar O.I., 2018;. Bondar O., 2017; Ulytsky O., 2018; Ulitskiy O.A., 2018; Denisov N., 2017).

The information under control and observation is shown on the right in Fig. 1.

- Elements of the Nature Reserve Fund (Fig. 1). The system contains 147 items of the NRF of Donetsk region and 195 items of Luhansk region with a brief description of infringements recorded since the beginning of the fighting.The information regarding the majority of described items is obtained from official archives. On the other hand, the information concerning the infringement at any particular element of the NRF has been recorded based on unofficial sources.
- Elements of industry and critical infrastructure (Fig. 2). The locations of industrial elements and critical infrastructure are determined using the Earth remote sensing data.It is known, that such data are not very accurate, so their position on the map is approximate. All the objects are divided into 8 different categories.The list of objects is not full and merely displays those of them where any accidents caused by the fighting have taken place.
- Disruption of working processes at infrastructure objects (Fig. 3).Such information is collected from open sources (reports of the National Security and Defense Council of Ukraine, reports of the OSCE Special Monitoring Mission to Ukraine, media

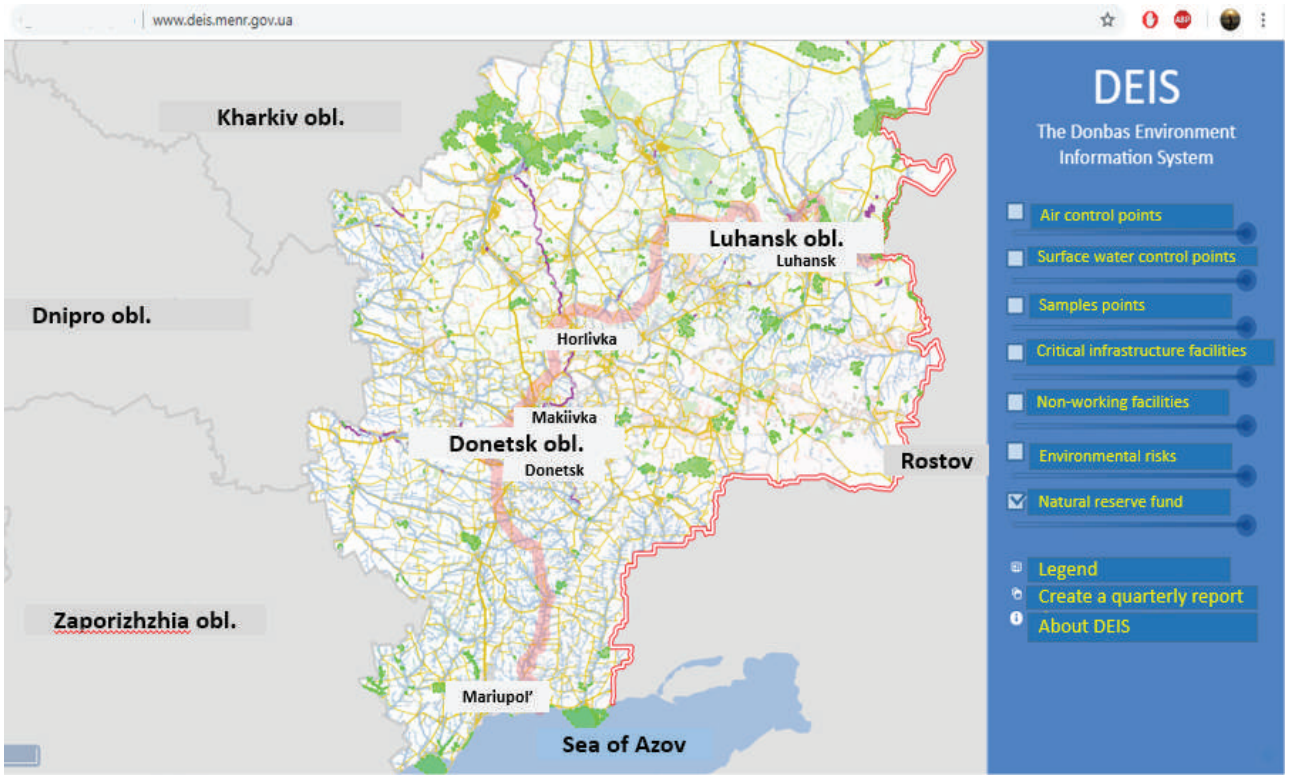

Fig. 1. Map of Donetsk and Luhansk Regions presented in DEIS involving the elements of the Nature Reserve Fund (NRF)

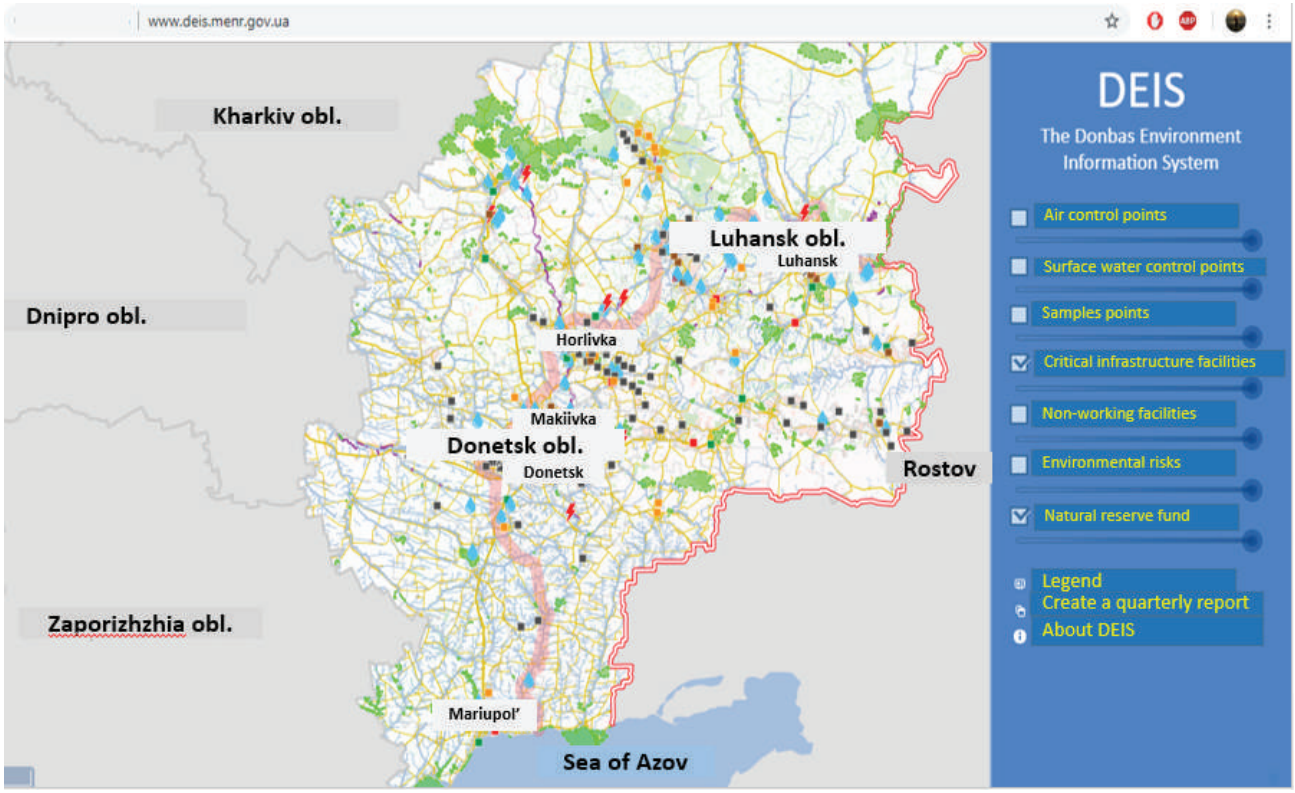

Fig. 2. Map of Donetsk and Luhansk Regions in the DEIS involving the elements of the critical infrastructure

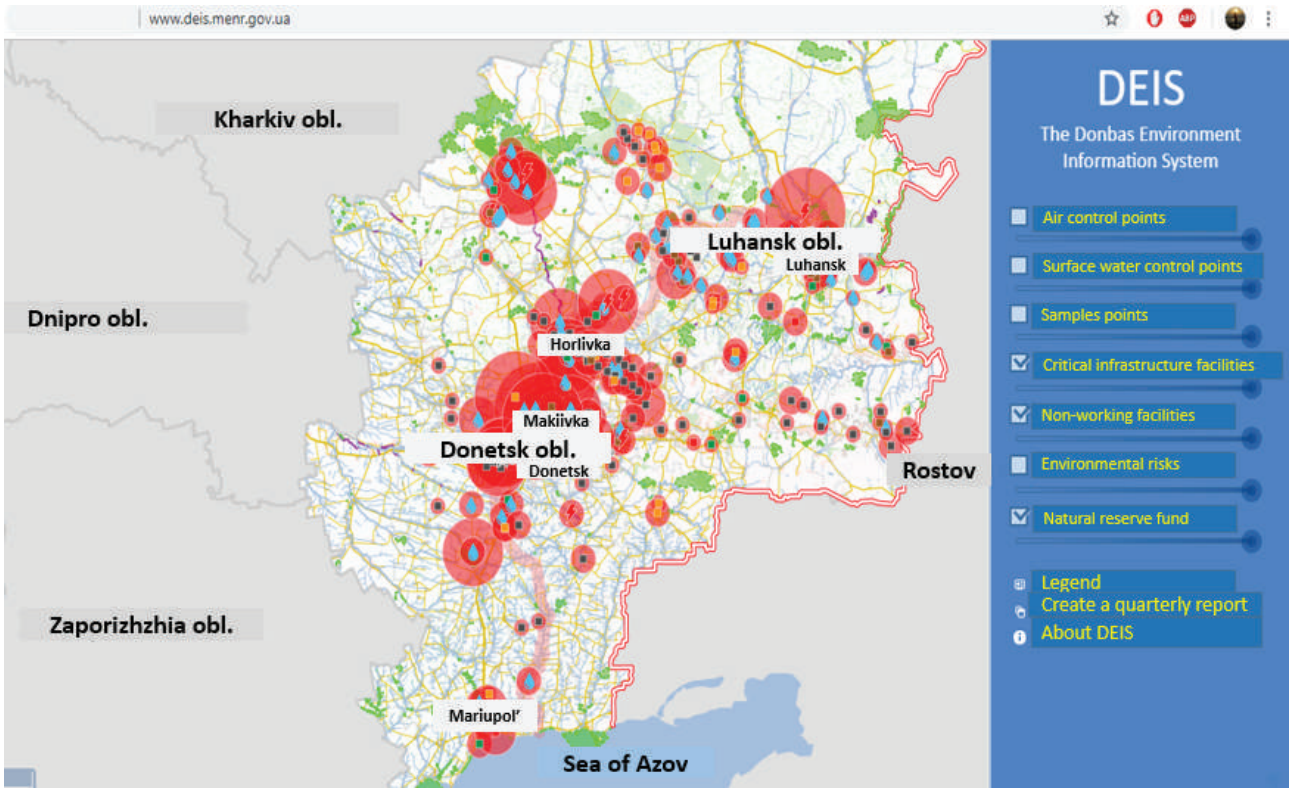

Fig. 3. Map of Donetsk and Luhansk Regions in DEIS involving the elements of critical infrastructure and disruption of working processes

reports). In the process of information base formation, the primary analysis and sampling were undertaken. At the same time, the open source data need to be verified. The information can be used for analytical and research purposes, with the further involvement of additional sources and data verification methods.The information in the section is divided into two categories - the official reports of the national departments and the data from the open unofficial sources.

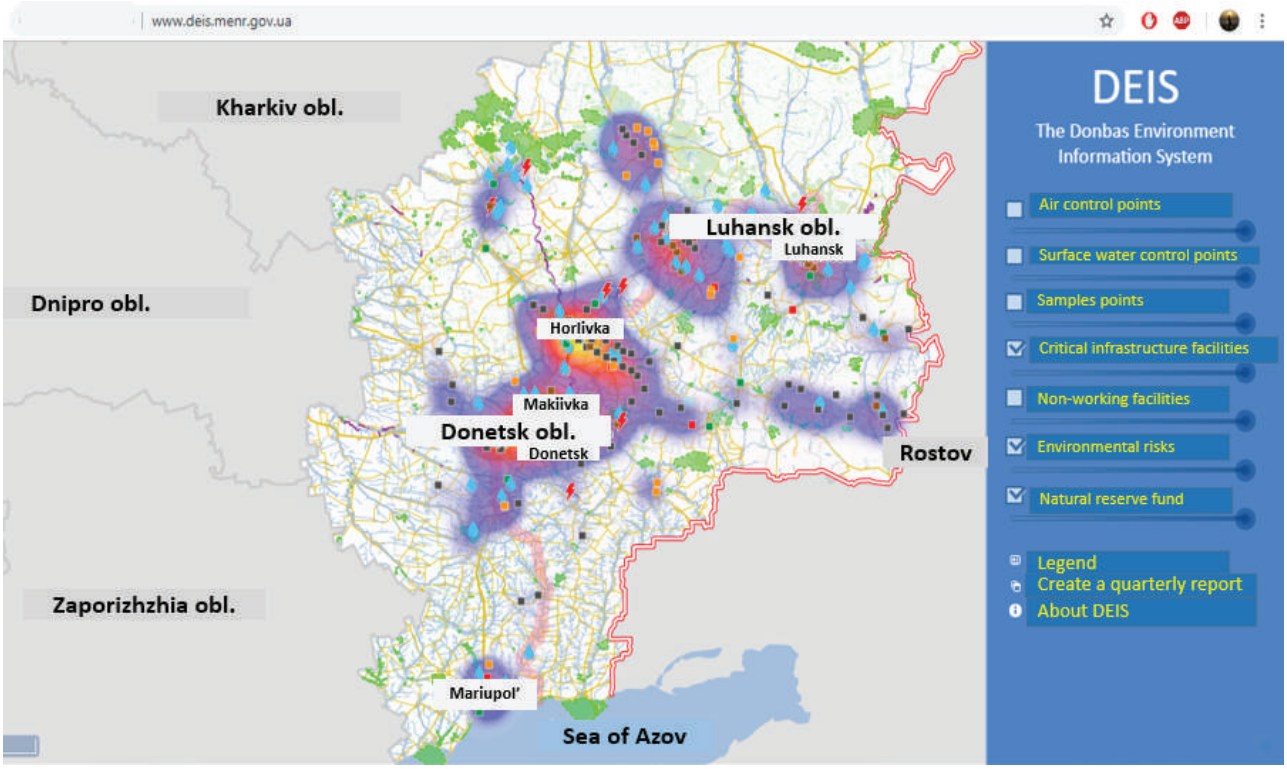

Fig. 4. Map of Donetsk and Luhansk Regions in DEIS involving the elements of critical infrastructure and environmental risks

- Environmental risks (Fig. 4). Environmental risks of critical infrastructure elements were determined on the basis of peer review, taking into account information about the type of activity and location.

Monitoring of atmospheric air (Fig. 5). Data on the quality of atmospheric air comes from automated measurement stations and are provided by the Department of Ecology and Natural Resources of Donetsk Region State Administration. The system contains 7 monitoring stations for atmospheric air (20 indicators). The data from automated stations are

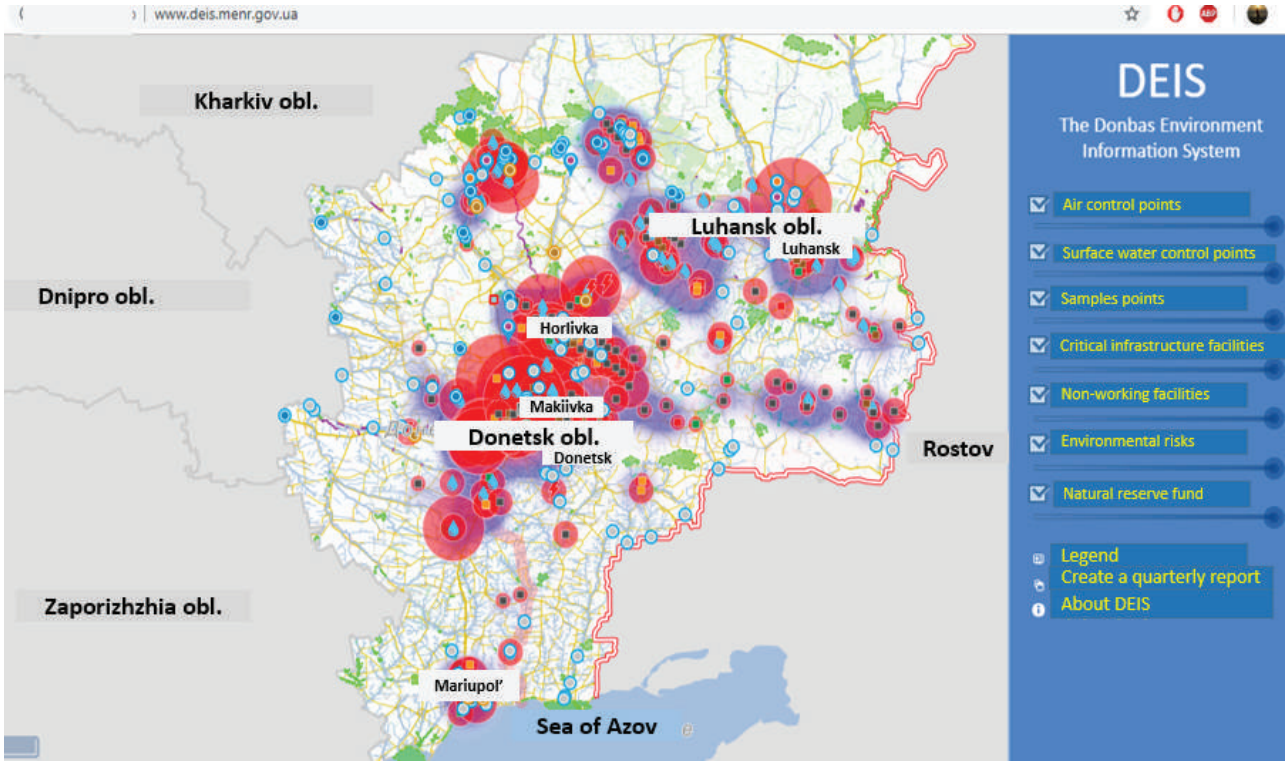

Fig. 5. Map of Donetsk and Luhansk Region in DEIS involving the areas of territorial risk

updated on daily basis.

Surface water monitoring (Fig. 5). Data on the condition of water surface is provided by the Siversky-Donets Basin Water Resources Administration of Ukraine. The system contains the monitoring data on the condition of water surface of the Siversky Donets river basin since 2000. The number of data sets depends on the period selected and the operating conditions. This section also includes data from 2 the indicators of danger.

Environmental monitoring involves monitoring the environmental status, assessing the capacity of the environmental impact and predicting the consequences of its results for human health and the environment (Mossner,2001; Ulanowicz, 2004).

Critical infrastructure elements can be considered as permanent sources of environmental pollution. Their emissions must be monitored by an automated system

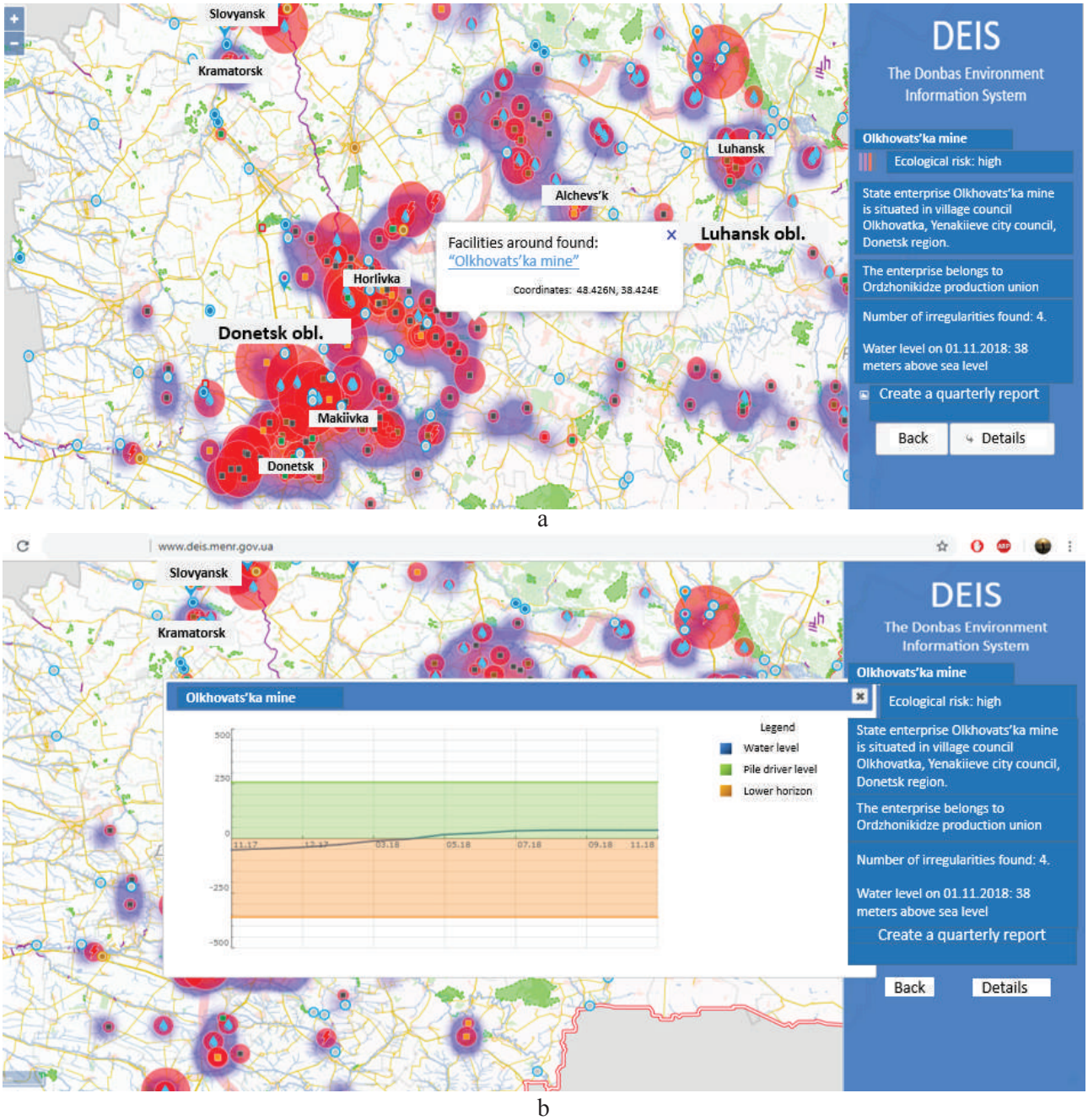

Fig. 6. Graphic report (level of flooding) at the Olkhovatska mine

automated stations of the Department of Ecology and Natural Resources of the Donetsk Regional State Administration.

Table 1 shows the legend of the interactive map of Donetsk and Luhansk regions in DEIS involving providing the real-time environmental data. Currently , considering the ongoing military operations , this is difficult to achieve. Automated control systems must necessarily become basic in cities and industrial centers (Malymon , 2009; Loreau, 2002; Balvanera,

Table 1. Symbols on the map of Donetsk and Lugansk regions in DEIS involving the hazard indicators

Sampling points	
	Sampling points of the OSCE Project Co-ordinator in Ukraine
	Sampling points of other organizations
Stations to monitor atmospheric air and surface water	
	Stations of air quality monitoring of Donetsk Regional State Administration
	Stations of surface waters' quality control of the Seversky-Donets Basin Water Resources Administration
	Closed stations of surface waters' quality control of the Seversky-Donets Basin Water Resources Administration
Elements of nature reserve fund and elements of critical infrastructure	
	Territories of elements of nature reserve fund
	Elements of the metallurgical industry
	Elements of the chemical and coke industry
	Elements of the mining industry
	Elements of the machine-building industry
	Elements of the energy industry
	Elements of water supply and drainage
	Other elements
Environmental risks	
	Maximum risks
	Minimal risks
Infringement at the elements	
	> 20 11-20 6-10 2-5 1
Surface waters	
	Rivers
	Channels
	Water elements
Transport infrastructure	
	Highways
	Railways
Territories	
	Settlements
	Industrial elements
	Forest
Borders	
	State border
	Borders of the regions
	Boundaries of districts
	Line of delimitation

2006; Dzhygyrey, 2007; Lavryk, 2002; Talanchuk, 1991; Maslov, 2005).

For example, using this system, you can obtain a graphic report for a coal mining enterprise (Fig. 6a) and see the level of its flooding (Fig. 6b)

You can also obtain a quarterly report on the of

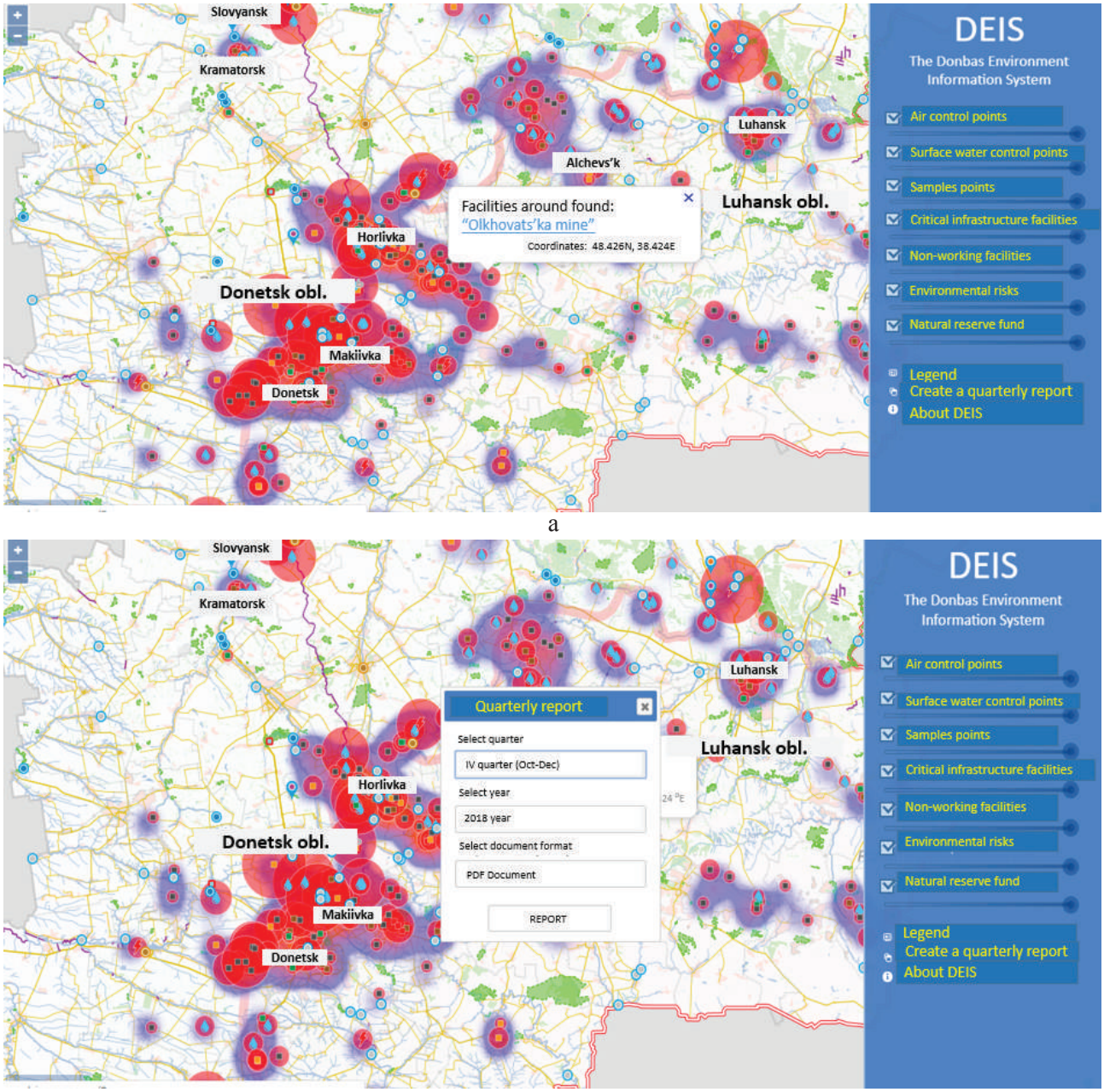

Fig. 7. Quarterly report on the state of the environment in the East of Ukraine

the air condition, water surface, about infringements of the critical infrastructure elements, flooding of mines in the eastern part of Ukraine (Fig. 7).

During the analysis of the risks affecting the emergency situations, we identified: a) equipment/plants where an accident is likely to occur and which have the highest emission of hazardous substances; b) the enterprises where accidents have the highest probability of occurring and from which hazardous emissions can affect the nearby territory as well; c) the zones of the highest pollution, their type, and level of possible negative impact; d) facilities which appear in such zones and should be under permanent monitoring (high priority monitoring).

The safety assessment of each facility which is included to the list of high priority monitoring involves analysis of the technological environment, presence of dangerous substances, their chemical, physical, thermophysical and other properties, which reflect the danger level. During the analysis we estimated a) the probability that dangerous substances can be released and enter the atmosphere; b) the probability that dangerous process can occur within equipment, pipelines, including uncontrolled reactions.

From a safety point of view, the main emphasis is focussed on humans. As elements of the ecosystem, where the impact of accidents is possible the following components, should be considered: flora and fauna; air; water (rivers, reservoirs, groundwater, sea water); land; other features of influence.

Conclusions. The authors have studied and determined the boundaries of the territorial risk zones distribution, which are divided into several levels depending on the potential danger.

The information regarding the potential risk distribution and population density in the researched area gives a quantative estimation of social risk. In order to obtain this, it is required to calculate the number of people affected in accordance to each possible scenario of accident and hazardous source, and then define the frequency of such events F, which would affect N and more people. As a result, the criterion of the possible risk will be defined not by the number of the singular event, but the curve built based on the various accident scenarios taking into account their probabilities.

The main idea of DEIS system development and support is to create a complex hierarchical structure enabling users to collect, process, store and sort the information. Such interaction will allow a permanent estimation to be made of any emergency cases, and, based on information support, a quick decision to be made focusing on providing a environmentally safe environment.

To ensure that the results of mathematical modelling can help in making decisions in a given situation, they should be transmitted into GIS and website online, and likewise, the data from GIS should be recognized and used in the mathematical modelling calculations. Such interaction will allow the best possible outcome to be obtained from monitored and modelled data, and, further, allow the area of GIS application to be extended.

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The prediction of ground water recharge of landslide areas in Dnipropetrovsk region

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Abstract. The forecast of groundwater level together with the observation network of wells are important and mandatory components of hydrogeological monitoring. The reliability of predictive calculations is achieved by reasonable definition of boundary conditions (inverse hydrogeological problem), correct calculation of hydrogeological parameters (inverse problem), and reasoned choice of methods (inductive problem). The classical forecast of the level regime of groundwater is a direct hydrogeological problem.The calculated dependences are proposed for four variants of hydrogeological conditions in relation to landslide-prone areas. The first and second variants are watered ravine with boundary conditions of the first and second kind. The third option is a special case of boundary conditions of second kind "impermeable boundary". The fourth option considers the periodic watercourse formation in the water intervals of the time climate series. A comparative analysis of four hydrodynamic schemes "infiltration band" in unlimited and semi-bounded layers and half-plane is performed under the same conditions to estimate the error of schematization. Significant differences in the calculation results confirm the need for a clear choice of the design scheme. A method of accounting for evaporation from the groundwater surface lying above the critical depth was proposed. This scientific approach allows accurate and detailed characterization of the average monthly groundwater regime in the course of a year. Multivariate calculations allow us to assert that the main mode – forming factor at the depth of groundwater below the critical depth is infiltration replenishment. Evaporation is a negative component of the water balance. Its value depends on the depth of groundwater, lithological composition of the host rocks, vegetation cover and complex climatic factors. Accounting for the evaporation of ground water in the forward estimates is required if they lie above the critical depth. The critical depth for the territory of Dnipropetrovsk region is assumed to be 2.0 m. At this depth of groundwater level from the earth's surface, the evaporation rate is zero. The maximum evaporation or evaporability corresponds to the position of groundwater at the surface of the earth. The maximum evaporation is 800 – 820 mm for Dnipropetrovsk region.The evaporation value increases inversely with the depth of its occurrence from the surface of the earth when the rise of the groundwater level occurs above the critical depth. The process of changes in the groundwater level in the unsteady filtration regime is described by two-dimensional differential equations of the second order in partial derivatives of parabolic type. This equation has analytical partial solutions for all considered variants of boundary conditions with regard to the problems of meliorative hydrogeology. It is possible to transform correctly to hydrogeological conditions of landslide slopes using numerical forecast.Infiltration nutrition indices were calculated by comparing the monitoring data with the values of evaporation through the soil surface.

Keywords: groundwater, forecast, level, hydrodynamic schematization.

Прогноз рівневого режиму підземних вод зсувонебезпечних територій в Дніпропетровській області

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Анотація. Прогноз рівневого режиму підземних вод відповідно даних спостережної мережи свердловин є важливою і обов›язковою складовою гідрогеологічного моніторингу. У комплексі з іншими дослідженнями такі сплановані тривалі спостереження є науковим підгрунтям ефективних природоохоронних заходів гідрогеологічної спрямованості. Достовірність прогнозних розрахунків досягається визначенням граничних умов (зворотна гідрогеологічна задача), коректним розрахунком гідрогеологічних параметрів (інверсійна задача), однозначно аргументованим вибором методів рішення (індуктивна задача). Класичний прогноз рівневого режиму підземних вод виконують рішенням прямої гідрогеологічної задачі. Для чотирьох варіантів гідрогеологічних умов запропоновані розрахункові залежності стосовно зсувонебезпечних територій. Перший і другий варіанти - обводнена балка з граничними умовами першого і другого роду. Третій варіант передбачає окремий випадок граничної умови другого роду «непроникний контур». Четвертий варіант розглядає періодичне утворення водотоку

у водні інтервали часового кліматичного ряду. Для оцінки похибки схематизації виконаний порівняльний аналіз чотирьох гідродинамічних схем («смуга інфільтрації» в необмеженому і навпівбмеженому пластах та навпівплощині в цих же умовах). Суттєві розбіжності результатів розрахунків підтверджують необхідність однозначного вибору розрахункової схеми. Запропонована методика обліку випаровування з поверхні ґрунтових вод, що залягають вище критичної глибини. Ця методика дозволяє охарактеризувати середньорічний режим підземних вод і протягом року. Багатоваріантні розрахунки дозволяють стверджувати, що головний режимоутворюючий фактор при глибині залягання підземних вод нижче критичної глибини це інфільтраційне живлення. Випаровування є негативною складовою водного балансу. Його величина залежить від глибини залягання підземних вод, літологічного складу вміщуючих порід, рослинного покриву і комплексу кліматичних факторів. Якщо ґрунтові води залягають вище критичної глибини, то облік їх випаровування при прогнозних розрахунках є обов'язковим. Для території міста Дніпро і Дніпропетровської області цей важливий параметр в наших розрахунках становив 2,0 - 2,2 м. При такій глибині залягання рівня ґрунтових вод від поверхні землі витрата їх на випаровування дорівнює нулю. Максимальне випаровування або випаровуваність відповідає їх зниженню біля поверхні землі і для регіону середнього Придніпров'я становить 800 - 820мм за рік. Роль випаровування зростає обернено пропорційно глибині їх залягання від поверхні землі, коли підйом рівня ґрунтових вод відбувається при їх заляганні вище критичної глибини. Процес зміни рівня ґрунтових вод в нестаціонарному режимі фільтрації описується двовимірними диференціальними рівняннями другого порядку в часткових похідних параболічного типу. Дане рівняння має аналітичні часткові рішення для всіх розглянутих варіантів граничних умов стосовно до завдань меліоративної гідрогеології. Можливим є коректне перетворення у гідрогеологічні умови зсувних схилів з використанням чисельного прогнозу. Порівняльний аналіз розрахункових схем, характерних для зсувних процесів міста Дніпра, показує істотні розбіжності в результатах розрахунків. Тому достовірність результатів прогнозних завдань істотно залежить від однозначного обґрунтованого вибору проектної схеми. Індекси інфільтраційного живлення розраховувалися шляхом порівняння даних моніторингу зі значеннями випаровування через поверхню ґрунту.

Ключові слова: ґрунтові води, прогноз, рівень, гідродинамічна схематизація

Introduction. Groundwater is basically a dynamic resource that may be expressed as the quantity of water measured by the difference between optimum and minimum water table within the aquifer (Jannat et al, 2014). Groundwater recharge includes atmospheric, surface and underground components of the water balance and depends on both climatic and anthropogenic factors (Herrera-Pantoja and Hiscock, 2008; Holman et al., 2009; Jyrkama and Sykes, 2007). Various studies have employed different methods to estimate groundwater recharge including tracer methods, water table fluctuation methods, lysimeter methods and simple water balance techniques (Mohan et al., 2018). The number of studies related to the assessment of hydrogeological risks in the catchment areas of rivers is increasing in many countries (Kalf, and Woolley, 2005; Yihdego and Webb. 2015, Yihdego and Webb, 2016).

Often predictions and operation assessment using numerical models proceed without making an adequate conceptual groundwater balance model (Yihdego and Khalil, 2017). Landslides are one of the most common and dangerous natural phenomena in areas with rugged relief, including gullies and ravines. It is very difficult to predict landslides because of the complex mechanisms that affect their activation.

Therefore, research on landslide prevention and mitigation mainly focuses on the distribution forecasting of unstable slopes that are prone to landslides in specific regions and under multiple external forces (Zeng et al, 2017). The prediction of the spatial distribution of unstable slopes, termed landslide susceptibility zonation, is important in assistance with government land-use planning and in reducing unnecessary loss of life and property.

The relationships between rainfall, hydrology and landslide movement are often difficult to establish (Malet et al, 2005). In this context, ground-water flow analyses and dynamic modelling can help to clarify these complex relations, simulate the landslide hydrological behaviour in real or hypothetical situations, and help to forecast future scenarios based on environmental change. Slow-moving landslides show complex mechanical and fluid interactions (Van Asch et al, 2009). Parameterization of hydrological and geomechanical factors by field and laboratory tests to describe the movement pattern of these landslides is difficult. The complete assessment of landslide susceptibility needs uniformly distributed detailed information on the territory (Sdao et al., 2013). This information is often fragmented, heterogeneous and related to the temporal occurrence of landslide phenomena and their causes.

The main goal of our research was to conduct a comparative analysis of the design schemes typical for landslide processes in Dnipro city.

Materials and methods. Four types of landslide slopes in Dnipropetrovsk region were identified taking into account the prevailing hydro-geological conditions conditions (Yevgrashkina et al, 2017; Yevgrashkina et al, 2018). First variant of hydro-geological conditions of landslide slope: ravine, pond and watercourse are the first kind boundaries (Fig.1). The second type: ravine, pond and watercourse are the second kind boundaries (Fig.2).

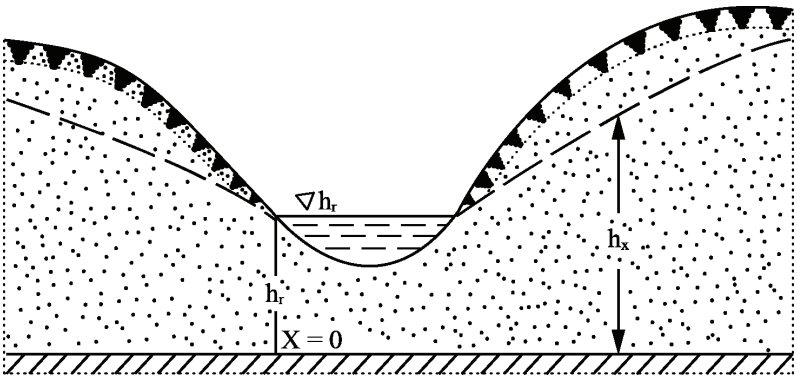

Fig. 1. First variant of hydrogeological conditions of landslide slope

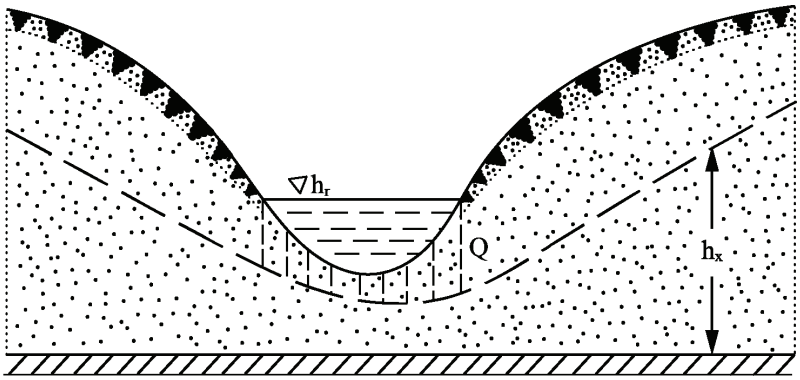

Fig. 2. Second variant of hydrogeological conditions of landslide slope

There is no water flow in the ravine (Fig.3). Two options are considered here.

The centre of the ravine with reasonable assumptions can be considered as a boundary of the II kind with a homogeneous structure of the aquifer (Fig.3a). In this case, the underground flow does not go up, but is combined with the flow from the opposite slope. As a result, they together change the direction under the bottom of the ravine to perpendicular r.

The second option (3b): the opposite slope is composed of weakly permeable rocks. This is a classic example of a particular case of boundary conditions of type II "impermeable boundary". The flow rate in this direction is equal to zero.The watercourse in the ravine occurs periodically in years with high rainfall. In this case, the forecast problem is solved by time intervals reflecting changes in hydro-geological conditions. A detailed characterization of infiltration feed and monthly evaporation is necessary as initial data to calculate the negative component of groundwater water balance – their evaporation rate, if they lie above the critical depth.

Results. The process of change in the level of groundwater in the unsteady filtration regime is described by two-dimensional differential equations of the second order in partial derivatives of parabolic type (Bochever et al, 1969):

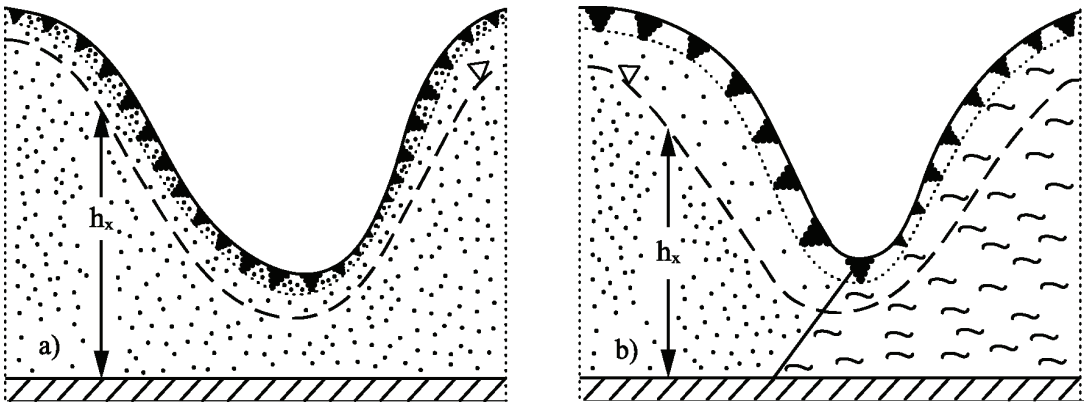

Fig.3. Third variant of hydrogeological conditions of landslide slope

(a) homogeneous structure of the aquifer; b) impenetrable opposite slope

$$\frac{\partial^2 h}{\partial x^2}+\frac{\partial^2 h}{\partial y^2}+\frac{\varepsilon}{T}=\frac{1}{a}\frac{\partial h}{\partial t} \quad (1)$$

where

h

x, y distance from the aquiclude to the surface, m;

$\varepsilon -$ spatial coordinates of the calculated points, m;

$T -$ infiltration feed, m/day

$a -$ water supply, m^2/day;

$t -$ level conductivity, m^2/day;

the temporal coordinate, the time of the forecast, day.

This equation has analytical partial solutions for all considered variants of boundary conditions (Rudakov and Andreyeva, 1970; Yevgrashkina and Andreyeva, 1973). It is possible to transform to hydro-geological conditions of landslide slopes correctly using numerical prediction. Two computational schemes are applicable for the first variant of boundary conditions (Fig.1). The first scheme - the infiltration band in the semi - bounded layer will be legitimate if the ravine is parallel to the next one. This does not mean necessarily that the ravine is watered. The width of the infiltration strip is equal to the distance from the water edge in the watercourse to the highest point of the watershed (Fig.4).

Application of the scheme "half-plane infiltration in a semi-bounded formation" in the modification $b_1 = 0$ is appropriate if there is no parallel ravine, as in the previous scheme (Fig.5).

Variety of scheme $b_1 \neq 0$ in the study area is absent. Analytical solution of equation (1) for the computational scheme "infiltration band in a semi-bounded layer" (Fig.4b) has the following form:

$$z = 2\frac{\varepsilon \cdot t}{\mu}\left(i^2 erfc\,\xi^{ii} - 2i^2 erfc\,\xi^{i} + i^2 erfc\,\eta^{i}\right), \quad (2)$$

$$\xi^{ii} = \frac{x - b\cdot 2}{2\sqrt{a\cdot t}};\ \xi^{i} = \frac{x}{2\sqrt{a\cdot t}};\ \eta^{ii} = \frac{x + b\cdot 2}{2\sqrt{a\cdot t}};$$

The following designations are accepted in equation (2):

$z -$

the value of groundwater level rise above its initial

$\mu -$ position, m;

the coefficient of hydrocapacity, share units;

$i^2 erfc -$ tabulated function.

Analytical equation solution (1) has the form for the calculation scheme «half-plane infiltration in a semi-bounded layer»:

$$z = 2\frac{\varepsilon \cdot t}{\mu}\left(0{,}5 - 2i^2 erfc\,\xi^{i}\right), \quad (3)$$

Analytical solutions (2) and (3) correspond to the hydrogeological conditions shown in Figure 1.

Two design schemes in Figure.6 can be applied to the hydrogeological conditions shown in Figure 2 above.

The first design scheme-"band infiltration in an unlimited reservoir" (Fig.6a)

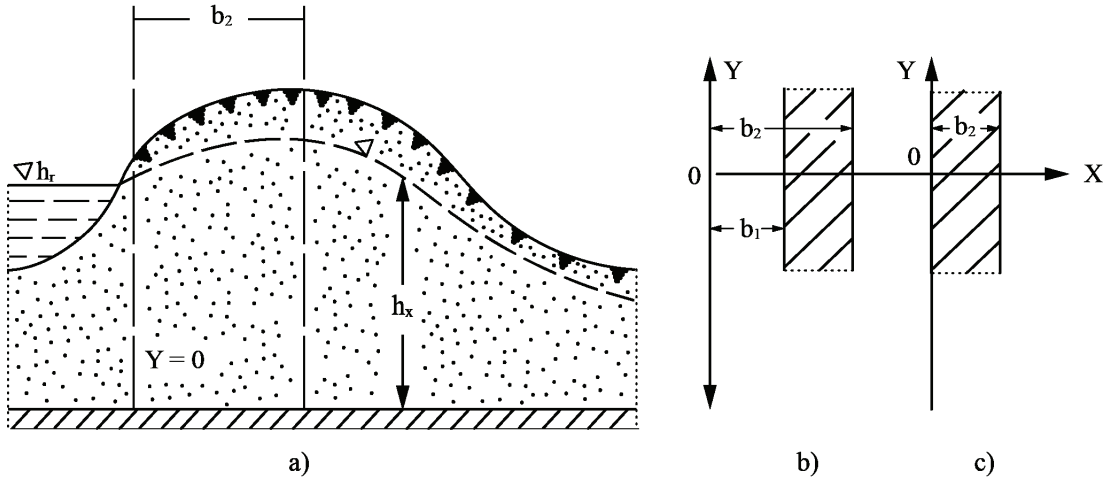

Fig.4. The block diagram, the band of infiltration in the semi- bounded layer

a –hydro - geological section; b - scheme of the section $b_1 \neq 0; b_2 \neq 0$;*c* - the scheme of the section $b_1 = 0; b_2 \neq 0$

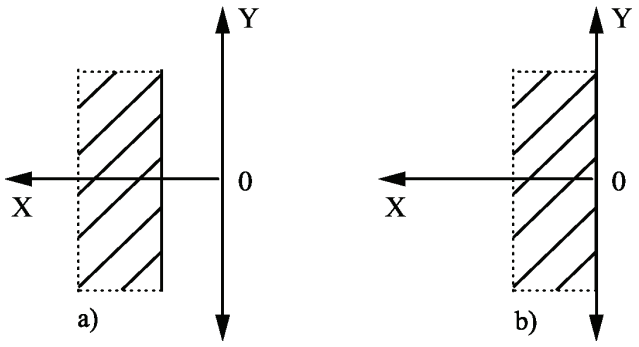

Fig.5. Computational hydrodynamic scheme " half-plane infiltration in a semi-bounded layer»
a - $b_1 \neq 0$; b-section diagram $b_1 = 0$;

$$z = 2\frac{\varepsilon \cdot t}{\mu}\left(i^2 erfc\xi_x - i^2 erfc\eta_x\right),\ \xi_x = \frac{x-b}{2\sqrt{a \cdot t}};$$

$$\eta_x = \frac{x+b}{2\sqrt{a \cdot t}}; \quad (4)$$

The second design scheme is "half-plane in an unbounded layer" (Fig.6b).

$$z = 2\frac{\varepsilon \cdot t}{\mu}\left(1 - 2i^2 erfc\xi\right),\ \eta = \frac{x+b}{2\sqrt{a \cdot t}}; \quad (5)$$

Two calculation schemes with boundary of II kind of "tight circuit" for the hydrogeological conditions are presented in Fig. 3. The scheme of the "strip infiltration in the bounded aquifer" (Fig.4 c) can be represented by the equation:

$$z = 2\frac{\varepsilon \cdot t}{\mu}\left(i^2 erfc\xi^{ii} - i^2 erfc\eta^{i}\right), \quad (6)$$

The calculated dependence (5) is valid for the scheme "half-plane in an unbounded aquifer" (Fig.5c). A comparative analysis of the calculation schemes typical for landslide processes of Dnieper city shows significant discrepancies in the results of calculations. Therefore, the reliability of the results of predictive problems significantly depends on the unambiguous reasonable choice of the design scheme.

It is known that evaporation gradually increases from the critical depth to the earth's surface. In our case, the evaporation from the groundwater level was calculated by the formula (Aver'yanov, 1978):

$$E = E_0\left(1 - \frac{z}{z_k}\right)^n, \quad (7)$$

where E – evaporation from groundwater level, mm;

E_0 – evaporation, mm;

Z – depth of groundwater level from the ground surface, m;

Z_k – critical depth, m

n – an exponent that depends on the above factors.

n is taken to be 1-3 for the conditions of the Dnipropetrovsk region. The practical calculation is performed in three variants n = 1, 2, 3 and the average value n = 2 is preferred more often. We will take groundwater evaporation into account when their level reaches a critical depth. In this case, we subtract the value from the infiltration feed in the calculated dependences (2) - (5).The dependence (5) takes the form:

$$z = 2\frac{(\varepsilon - u) \cdot t}{\mu}\left(1 - 2i^2 erfc\xi\right), \quad (8)$$

All the rest is likewise. The rise of the groundwater level will stop at $\varepsilon = u, z = 0$. The point depth is calculated from the surface of the earth. In this case, the condition $E = \varepsilon$ is fulfilled: in each case, we find from the solution (7) with respect to z .

$$z = \left(1 - \sqrt[n]{\frac{E}{E_0}}\right)z_k = \left(1 - \sqrt[n]{\frac{\varepsilon}{E_0}}\right)z_k \quad (9)$$

The territory of Dnipro city is dissected by several ravines. Hydrogeological conditions of the "Evpatoriyska" ravine were considered as an example. " Evpatoriyska " ravine is located in the southern part of Dnipro city within the watershed slope of the Right

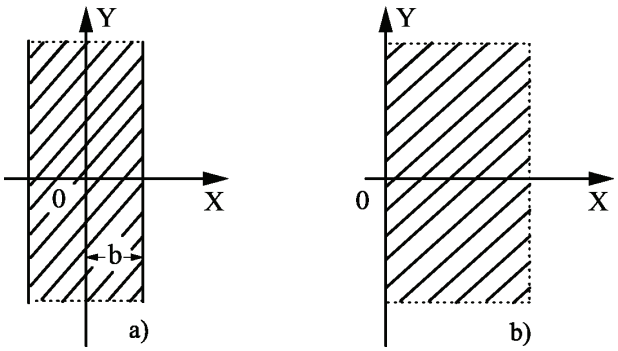

Fig.6. Band infiltration and half-plane infiltration in an unbounded layer a) band infiltration; b) half-plane

Bank of the Dnieper River. The average annual value of infiltration replenishment according to the results of treatment of regime observations is m/day or 6.2 mm / year.Substitute in the formula (9) the original data as follows:

$$\varepsilon = 6{,}2mm/year;\ E_0 = 800mm/year;\ z_k = 2{,}0m;\ n = 2.$$

$$z = \left(\sqrt{1-\frac{6{,}2}{800}}\right)\cdot 2 = 1{,}97m$$

Following the calculations, the rise of groundwater level in long-term incision in this area will cease when the depth of its occurrence from the ground surface is 1.97 m with account of evaporation. However, seasonal variations are possible. Large values of groundwater level rise are possible during the period when the maximum amount of precipitation falls with minimal evaporation. The average annual value of infiltration replenishment in February reaches a maximum value of 8.37mm with evaporation of 10.3 mm (Table.1).

Enter this data in the formula (9):

$$z = \left(\sqrt{1-\frac{8{,}37}{10{,}3}}\right)\cdot 2 = 0{,}2m.$$

According to the calculation it, follows that the groundwater level in February may be at a depth of 0.2 m from the earth's surface.

Discussion. Evaporation is a negative component of the water balance. Its value depends on the depth of groundwater, lithological composition of the host rocks, vegetation cover and complex climatic factors. Accounting for the evaporation of ground waters in the forward estimates is required if they lie above the critical depth. The critical depth for the territory of Dnipropetrovsk region is assumed to be 2.0 m.

At this depth of groundwater level from the earth's surface, the evaporation rate is zero. The maximum evaporation or evaporability corresponds to the position of groundwater at the surface of the earth. The maximum evaporation for the Dnipropetrovsk region is 800 – 820mm (Yevgrashkina et al, 2018).

Evaporation gradually increases from the critical depth to the earth's surface. This parameter is determined experimentally in lysimeters or by calculated dependences. Currently, standard methods for assessing infiltration nutrition at the regional level most often include a long-term assessment of soil moisture (Jannat et al., 2014).

This approach is used to estimate surface runoff, evapotranspiration, and recharge in the unsaturated zone. Another approach is used when water is discharged from the atmosphere to the surface of the earth.

Meanwhile, most of the precipitation passes through the surface of the earth and enters the unsaturated zone, while precipitation that does not penetrate forms surface runoff and flows into the river network (Yeh et al, 2007). Water in the unsaturated zone vertically seeps into the deeper soil layers under the influence of gravity.

Uncertainty in the calculation of infiltration supply and discharge of groundwater seriously hampers the development and implementation of effective environmental policies for groundwater management. Further studies on the hydrology of landslides should therefore be carried out on the basis of the various databases.

Conclusion. The substantiated definition of infiltration feed is the main factor in the reliability of the predicted calculation at the depth of occurrence of groundwater level below the critical depth. The role of evaporation increases inversely with their depth, if the rise of groundwaters exceeds their critical depth. The stabilization of the level corresponds to the depth of its occurrence of ground waters of 1.84 m without taking into account additional sources of technogenic

Table 1. Evaporation and infiltration replenishment of the territory of Dnipro city during one year

Balance elements	Balance sheet items by month												
	mm												mm
	1	2	3	4	5	6	7	8	9	10	11	12	year
Evaporation	8.86	10.3	22.5	55.2	93.8	134.3	178.5	150.9	93.8	43.1	17.4	11.0	819.75
Infiltration	3.69	8.37	4.44	1.14	0.9	1.14	-216	-2.01	-0.69	0.45	2.07	1.77	+23.97
м/сут 10^5													
Evaporation	0.27	0.34	0.75	1.84	3.13	4.48	5.95	5.13	3.13	1.44	0.58	0.37	
Infiltration	12.3	27.9	14.8	3.8	3.0	3.8	-7.2	-6.7	-2.3	1.5	6.9	5.9	

influence, including emergency situations. A significant error in the results of the forecast is proved by calculations due to insufficiently substantiated schematization of boundary conditions. Separate periods of the year are characterized by significant rise in groundwater level (up to 0.2 m from the surface of the earth).

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Social and geographical features of the formation of the modern labour market of Ternopil region

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Abstract. The article gives a detailed analysis of the processes of formation of the labour resource potential of Ternopil region as a labour excess region. The influence of the demographic component on the formation of quantitative and qualitative characteristics of labour potential is highlighted there. The study of patterns and factors in the formation of labour potential is inextricably linked with research on the labour market, which is the most important element of the market economy. Availability of labour potential brings a certain social and economic sense to the development of labour market, its effective functioning and improvement of the employment system of the population. Since the natural basis of labour potential is the population, a vital component in guaranteeing the stable and safe development of the state, the problems of optimal demographic development are extremely relevant. The article outlines current problems of unemployment of the population of Ternopil region, in particular young people; the causes of its occurrence are investigated there. It was established that the labour resource potential of Ternopil region is characterized by a high proportion of able-bodied persons, but a low level of employment. The main features of the labour resource potential are the decrease in its quantity due to the natural reduction of population and migration of able-bodied persons, deterioration of the age structure of the population as a result of "ageing", changes in the structure of employment in economic activity, narrowing professional structure of workers and imbalance in the labour market. This is a sign of exhaustion of the labour resource potential, which may negatively affect the development of certain sectors of the economy in the future. The research analyzes changes that took place in the structure of employment in the economy, starting from the 1940s up to the present; the consequences of stagnation of a significant number of enterprises in industry, construction and other industries (narrowing professional structure of workers in the economy, etc.) are shown there. The main reasons for the discrepancy between the supply and demand of the labour force in the region (unwillingness to work outside one's specialty, low salary, low level of qualification of employees) are indicated. Particular attention is paid to the migration of people of working age beyond the region, the main reasons that cause it, as well as the possible consequences for further development of the economy of Ternopil region.

Key words: population, labour resource potential, labour market, labour resources, economically active population, unemployment, employment of the population

Суспільно-географічні особливості формування сучасного ринку праці в Тернопільській області

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Анотація. У статті подано докладний аналіз процесів формування працересурсного потенціалу Тернопільської області як праце надлишкового регіону, висвітлено вплив демографічної складової на формування кількісних і якісних характеристик трудового потенціалу. Вивчення закономірностей та факторів формування трудового потенціалу невід'ємно пов'язано із дослідженнями на ринку праці - найважливішого елементу ринкової економіки. Наявність трудового потенціалу вносить певний соціальний і економічний сенс в питання розбудови ринку праці, його ефективного функціонування, поліпшення системи зайнятості населення. Оскільки природною основою трудового потенціалу є населення, важливою складовою визначальних для гарантування стабільного й безпечного розвитку держави, а проблеми оптимального демографічного розвитку є надзвичайно актуальними. У статті окреслено актуальні проблеми безробіття населення Тернопільської області, зокрема моло-

ді, досліджено причини його виникнення. Встановлено, працересурсний потенціал Тернопільської області характеризується високою часткою працездатних людей, але невисоким рівнем зайнятості населення. Головними ознаками працересурсного потенціалу є зменшення його кількості через природне скорочення населення і міграцію працездатних людей, погіршення вікової структури населення внаслідок «старіння», зміна структури зайнятості у господарській діяльності, звуження професійної структури працівників, незбалансованість на ринку праці. Це є ознакою виснаження працересурсного потенціалу, що може негативно відбитися в майбутньому на розвитку певних галузей господарства. У дослідженні проаналізовано зміни, які відбулися у структурі зайнятості населення у галузях господарства, починаючи від 40 років XX ст. до нашого часу, показано наслідки стагнації значної кількості підприємств промисловості, будівництва та інших галузей (звуження професійної структури працівників господарства та ін.). Вказано основні причини невідповідності між пропозицією та попитом робочої сили в області (небажання працювати не за спеціальністю, низька зарплата, низький рівень кваліфікації працівників). Окрему увагу звернено на міграцію людей у працездатному віці за межі області, основні причини, які її зумовлюють, а також можливі наслідки для подальшого розвитку господарства Тернопільської області.

Ключові слова: населення, працересурсний потенціал, ринок праці, трудові ресурси, економічно активне населення, безробіття, зайнятість населення

Introduction. The change in economic relations in Ukraine, transition of society to the market economy has forced workers to adapt to a new system of labour relations, and to the transformation of the labour market. An important feature of the labour market in Ternopil region, a territory which is marked by agrarian – industrial development, is the increase in the disproportion between the supply and demand for labour (increase in the reserve of the able-bodied population and reduction in the need for workers in the economy). This is the consequence of crisis in the economy, the lack of real reforms in most industries. The stagnation of production, the decay of all its branches has led to the emergence of unemployment and changes in employment, changes in the quality of labour and resource potential. The greatest changes have occurred in the level and structure of employment of workers. If under the planned socialist economy the emphasis was placed on full employment of the able-bodied population, currently under conditions of crisis the employment level is low, and there is real and hidden unemployment. So, in 2018, the employment rate was 51.0% of the population aged 15-70. Due to the closure and re-profiling of enterprises, optimization of enterprises in the sphere of services is constantly increasing the number of unemployed persons.

Materials and methods of research. Study of characteristics of the labour market today is one of the key tasks of modern geographic and economic science. Social geography today has significantly developed, is based on theoretical aspects, conceptual terminology apparatus and methodological developments, and can conduct a territorial-time analysis of labour and resource potential for assessing the real situation and forecasting the development of the economy and the social sphere.

Theoretical and methodological aspects of studying labour resource potential and the labour market are formed in the works of the following social geographers and economists: M. Baranovskyi, V. Brych, A. Holikov, M. Dnistrianskyi, K. Mezentsev, Ya. Oliinyk, A. Stepanenko, O. Topchiiev, O. Shablii and others.

The study of labour resource potential geography of the population at regional and state levels is reflected in the scientific work of: S. Bandura, D. Bohynia, I. Hudzeliak, S. Zlupko, E. Libanova, A. Dotsenko, M. Fashchevskyi, O. Khomra, and others.

In carrying out the research on demographic characteristics of the labour market of the region, the general scientific methods of research were used: analysis and synthesis, comparison, deduction; and specific-scientific: comparative-geographical, classification and typology, etc.

Results and their analysis. Labour resource potential includes a combination of social and economic relations that create the basis for the formation of a new productive, targeted force that arises from the application of certain conditions by society (Shablii, O.I., 2001). Labour resource potential is based on labour resources, which are determined not only by quantitative indicators but also by qualitative ones (age, level of education, qualification, etc.). Therefore, the same number of people of working age can produce different quantities of products that will differ in quality. This, in turn, affects the socio-economic development of the region.

The territorial structure of the economy, the development of the main and auxiliary sectors directly depends on the quantity and quality of labour resources, the peculiarities of the formation of the labour resource potential (Baranovskyi, 2009). In regions with a high population density, it is expedient to develop labour-intensive sectors of the economy, whose products can satisfy both intra-regional demand and the national economy.

The basis of the formation of labour resources potential is the total potential workforce in the population, that is, the able-bodied population. Under

current conditions, the total potential workforce of the region is constantly declining.This is occurring through natural population decline and due to the negative migration surplus. The signs of depopulation began to emerge in the mid-1970s, but were especially pronounced at the end of the twentieth - early twenty-first century. (Fig. 1). So, if up to 1993 the population of the region was still increasing (1,180.3 thousand people in 1993), then by the end of the century it had decreased to 1,152 thousand people, and as of January 1, 2018, it was 1,046. 2 thousand people. This is a consequence of a decline in fertility rates and an increase in mortality rates.

A significant proportion of the total potential workforce is taken up by the unemployed. The unemployed are considered to be able-bodied citizens in our country who are in search of a job, do not have sources of income as envisaged by the legislation of the country and are registered with the state employment service. The number of unemployed in 2005 was 42.3 thsd. persons, in 2018 – 53.1 thsd. persons. Accordingly, the level of unemployment was the highest at the end of the twentieth century, when the stagnation of industrial production came, and then, taking into account the "hidden" unemployment (part-time employment), this level reached 30% of the working-age population, in 2018 it was 11.9% (Table 1). This level would be significantly higher if the rural population was taken into account, people who have a yard/kitchen garden , but do not have any steady income from working there (except for providing for own consumption), but this population does not fall into the category of unemployed.

In the last three years, from 2016 to 2018, the number of unemployed in the region has declined somewhat. At the end of 2018, it was 1.3 thousand fewer than in 2015. The highest unemployment rate in the period 2000-2018 was observed in 2001 and amounted to 78.7 thsd. persons (Fig. 2) of the number of the able-bodied population in the region.

It should be noted that in Ternopil region there is a significant quantitative imbalance between demand for labour and its supply. In particular, the load of registered unemployed per one vacancy in region as a whole increased by 4 persons, and by the end of December 2016 it was 9 persons, and in 2018 – 13 persons. The indicator varied from 2 persons in the city of Ternopil to 232 persons in Shumsk district, 210 in Monastyrysk district, 104 in Husiatyn district (Derzhavna sluzhba statystyky Ukrainy, 2018).

As of December 31, 2018, 10,782 unemployed persons were registered at the Employment Centres, among them the share of women was 46.7%, young people under 35 years old – 36.9%, workers – 41.9%, people in government/local government service – 40.9%, persons who have additional guarantees for obtaining employment – 39.6%. An interesting and at the same time alarming fact is that among the unemployed persons, the largest category of people is those with higher education – 44% of their total, while in Ternopil Employment Centre – 80.9%.

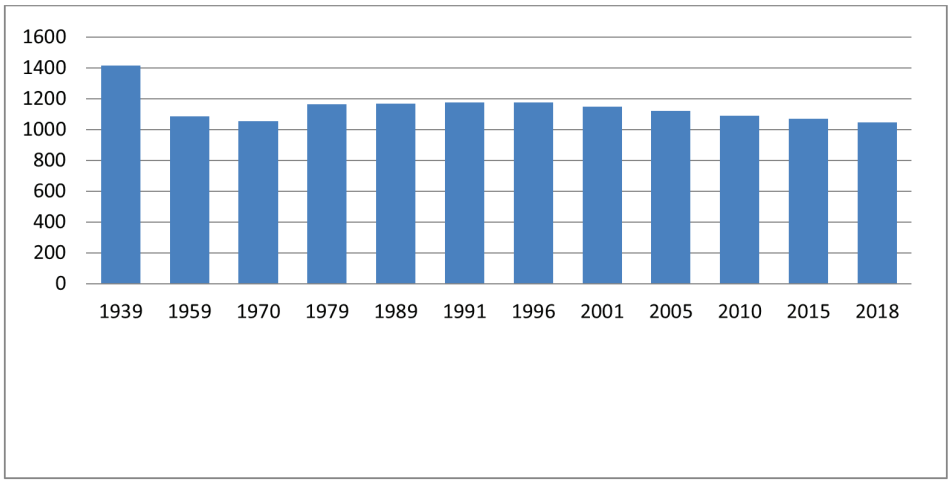

Fig. 1. The population of the Ternopil region from 1939 to 2018, thsd. people

The ongoing problem of the modern labour market is youth unemployment. Analysis of the labour market conjuncture shows, unfortunately, the social insecurity of young people, which is characterized by significant volumes, levels and duration of unemployment. In Ukraine, at present, there are not suitable conditions to attract young people to work and thus become involved in the field of economic employment. This reduces the level of social protection and generates a marginalization of a proportion of young people, resulting in incomplete use of its labour and creative potential (Libanova, 2007).

Under current conditions, the number of persons

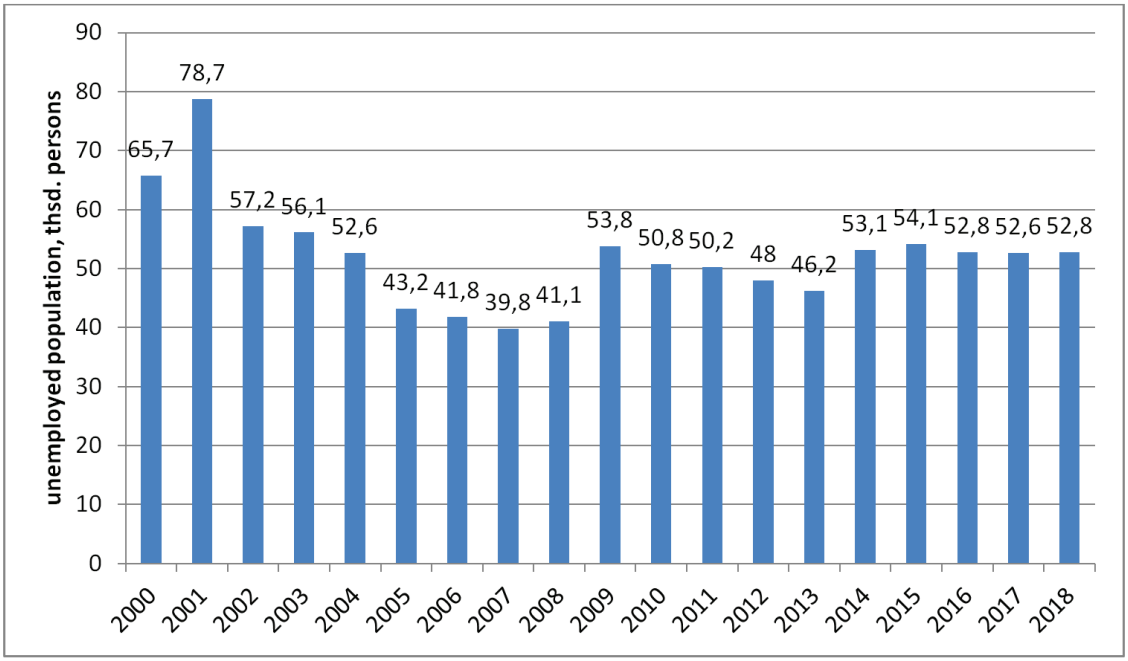

Fig. 2. Dynamics of the unemployed population of Ternopil region age from 15-70 years in 2000-2018, thsd. persons (according to the ILO methodology)

employed in the region slightly increased (in 2000 – 305.6 thsd. persons, in 2018 – 396.0 thsd. persons), which indicates the transformation processes in the economy, development of new types of economic activity, some modernization of production. Mostly these are people of working age. The non-active workforce (more than 315.6 thsd. persons), which can be added to economic activity in the future, is also a certain reserve for labour resource potential.

the XX century – at the beginning of the XXI century – they were employed in the service sector. Thus, in 1990, 165.1 thsd. persons worked in the manufacturing sector, and 148.4 thsd. persons in the service sector (in 1995, respectively 131.2 thsd. persons and 145.9 thsd. persons, and already in 2014 – 182.2 thsd. persons and 231.9 thsd. persons). With the general reduction of workers in both spheres, by 2000, the rate of decline was significantly higher in

Table 1. Population by economic activity (at the age of 15-70 years, thsd. persons) *

	2000	2005	2010	2014	2018
Economically active population	475.1	467.4	482.1	469.1	453.0
Employed	409.4	425.1	431.3	416.0	399.1
Unemployed	65.7	43.2	50.8	53.1	53.9
Economically inactive population	342.1	340.3	313.0	318.0	315.6

* According to the data of the Main Department of Statistics in Ternopil Region

The employment of the young population (aged 15-35) is low in the region, it amounts to 29.8% of the number of full-time employees, many young people cannot find a job after graduation (more than 12%). However, in some sectors (information and telecommunications, financial and insurance activities, trade and repair of motor vehicles, etc.), the proportion of young people is rather high (more than 30%).

There have been significant changes in the structure of employment in the economy (Table 2).

Thus, if in the pre-crisis period most workers were employed in production, then at the end of

the branches of production, which led to a significant reduction in its share in the economy of the region (in 1980 – 52.5%, in 1995 – 48. 6%, in 2018 – 43.8%). The largest reductions were observed in industry and transport (Table 2), somewhat lower in the sphere of services, and in some of its branches there was even an increase in workers (trade and catering, financial activity, public administration and agriculture and forestry).

As a result of different rates of change in the number of employees in the sectors of the economy, their share in the structure also changed.

This was also facilitated by a certain increase in

Table 2. Employment in Ternopil region by types of economic activity, thsd. persons *

	Years									
	1940	**1960**	**1970**	**1980**	**1992**	**1995**	**2000**	**2005**	**2010**	**2018**
Total	***78.7***	***138.5***	***132.6***	***313.5***	***327.5***	***284.5***	***305.6***	***425.1***	***422.1***	***396.0***
Industry	73.1	29.6	65.6	92.4	87.8	73.0	59.9	50.8	46.1	38.8
Agriculture, hunting, forestry, fish farming	10.7	12.3	15.6	27.0	30.3	19.3	102.5	107.2	111.2	130.0
Construction	3.0	13.9	22.9	26.4	23.0	17.3	11.3	15.3	17.1	30.0
Transport	9.9	16.0	25.0	29.3	31.9	19.6	17.4	18.9	19.1	19.0
Communication	2.1	2.2	4.8	5.9	6.1	6.0	2.4	1.5	3.6	3.6
Trade, catering, material and technical supply and sales	13.4	16.0	28.1	34.2	32.8	23.9	21.2	62.2	84.9	77.0
Real estate operations	1.2	3.5	5.9	11.4	16.2	12.9	6.6	9.1	15.2	3.3
Health care and social assistance	3.2	13.5	19.3	25.4	34.8	33.6	31.7	30.3	30.1	30.2
Education	10.6	21.0	30.6	40.4	50.8	53.7	39.8	47.1	46.5	46.3
Governance	9.5	5.7	8.2	10.0	9.0	11.6	11.9	21.0	24.5	23.0
Financial activities	1.2	1.2	1.7	2.6	3.3	3.7	2.6	3.6	4.8	3.5
Science and scientific service	0.1	1.0	0.4	1.9	1.9	1.5	5.4	5.8	6.2	6.0
Other types of economic activity	9.3	2.6	4.5	9.6	7.4	8.4	10.1	12.3	12.8	15.3

* Calculated according to the data of the Main Administration of Statistics in Ternopil Region

the number of workers in the region's economy, mainly due to transformations in agriculture, construction, education, trade and financial activities. The increase is not entirely justified (in comparison with 1990, by 2 times) in public administration, indicating the absence of reforms in the administrative and managerial sphere, a situation which may be changed as a result of decentralization in the field of governance of the country (Brych, 2003).

Another feature of labour and resource potential is the narrowing of the professional structure of workers of the economy, which occurred as a result of

Table 3. Demand and supply of workforce in districts of Ternopil region, persons *

Districts	**Number of registered unemployed**			**Number of workers required by employers**			**Load on one vacant workplace**		
	2005	**2010**	**2018**	**2005**	**2010**	**2018**	**2005**	**2010**	**2018**
In region	43,832	15,260	15,742	1,835	1,053	1,251	24	14	14
Berezhany	1,536	768	850	64	17	33	24	45	28
Borshchiv	3,918	976	1,050	33	34	20	119	29	53
Buchach	3,628	1,055	728	45	14	24	78	75	32
Husiatyn	3,768	1,545	1,378	88	47	21	43	33	64
Zalishchyky	1,857	365	458	26	15	16	71	24	28
Zbarazh	3,519	1,106	1,029	83	40	50	42	28	48
Zboriv	2,962	764	813	75	27	25	39	28	20
Kozova	2,322	742	716	20	14	15	116	53	23
Kremenets	3,992	1,445	1,439	57	70	54	70	20	25
Lanivtsi	1,757	493	534	23	32	22	76	15	18
Monastyryska	1,318	339	323	54	25	22	24	14	28
Pidvolochysk	1,184	500	607	87	31	14	14	16	23
Pidhaitsi	892	338	299	57	45	33	16	8	16
Terebovlia	2,023	555	819	36	44	47	56	13	8
Ternopil	5,507	2,920	3,177	999	539	811	28	8	8
Chortkiv	1,729	510	799	57	20	24	30	26	36
Shumsk	2,020	839	723	31	36	20	65	23	28

*According to the data of the Main Administration of Statistics in Ternopil Region

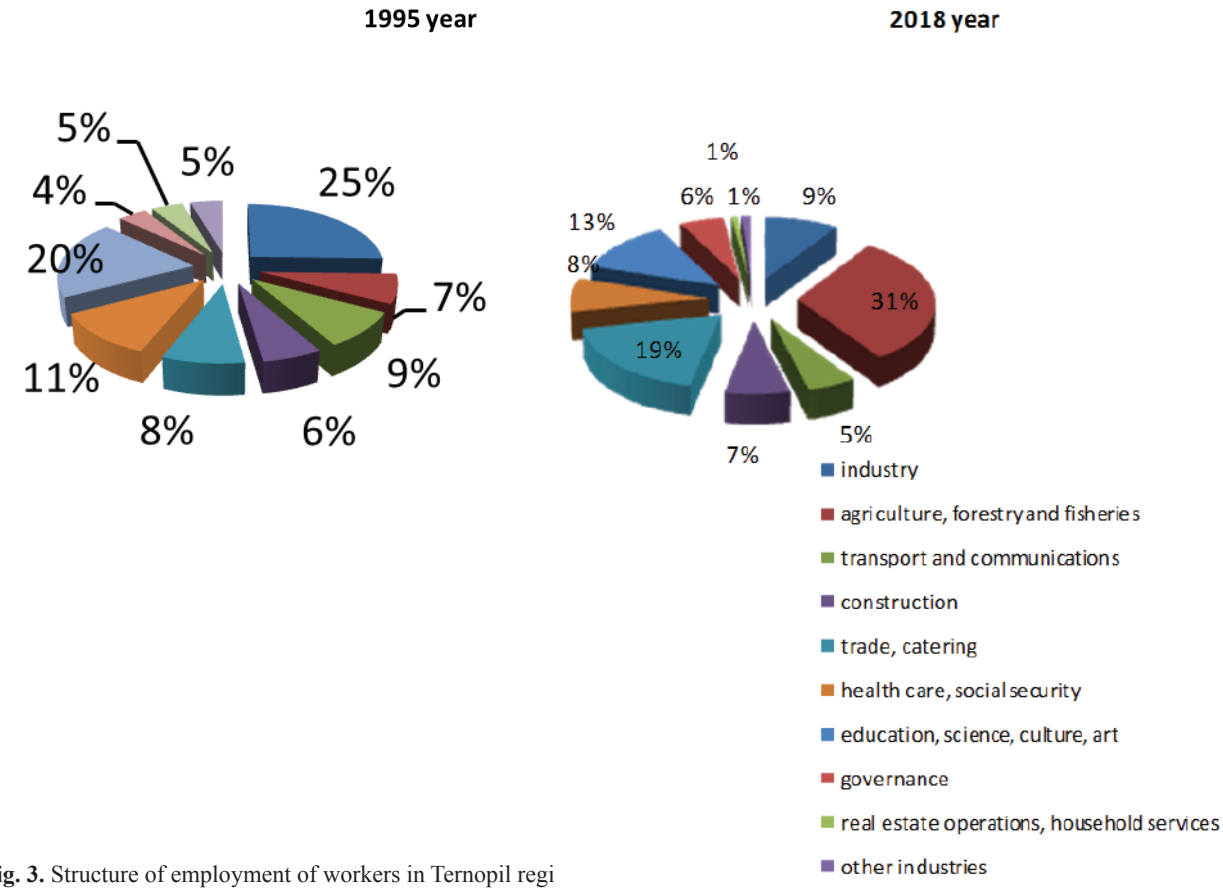

Fig. 3. Structure of employment of workers in Ternopil regi
economic activity, in % (Source: Derzhavna sluzhba statystyky Ukrainy)

stagnation of many enterprises of industry, construction and other branches (Fedunchyk, 2016). The low capacity of employers in the region, as well as the low labour cost, make migrant workers more or less concentrated in other regions of the country or abroad. Predominantly, these people do not work at their professional level, gradually losing their skills. This contributes to the exhaustion of labour resources, both in terms of physical and qualitative characteristics.

Due to the crisis in the economy and lack of real reforms, the region has a low degree of flexibility in supply and demand in the labour market. With a total load of 15 persons per 1 vacant workplace (in Ukraine 11 persons) there is a discrepancy between the demand for workers of different qualifications and professional level and their availability in the region. Among the sectors that show the greatest burden on one job, are agriculture (28 people), as well as forestry and fisheries (27-28 people), although this indicator has decreased by 6.6 times in the last 10 years (Table 4). The highest load is in Husiatyn, Chortkiv, Shumsk, Monastyrysk, Berezhany districts.

Disproportion in the labour market of the region was the highest at the end of the twentieth century, now it was partially offset by a number of reforms in the services sector and the increasing number of workers who migrate abroad for higher earnings . Officially, the difference between the availability and demand for workers for the filling of vacancies in the region was in 2018 (1.4 thsd. persons), the largest one being observed in the city of Ternopil and in Terebovlia district. The most demanded professions in the region are labour professions (almost 500 persons), workers in the services and trade, and the least demanded – workers in agriculture, forestry and fishery. The discrepancy between the availability of labour force and its employment is determined by another factor – the reluctance to work outside one's specialty and for low salary. There are interruptions in the reproduction of the vocational qualification structure of workers necessary for the restructuring of the economy.

Having studied the structure of demand and supply of labour resources and employment of the region's population in various sectors of the economy, we note that the total unemployment in recent decades in the oblast has tended to decline (by 2.8 times in 2018, compared with 2005). Analysis of the demand and supply of workforce among professional groups over the past thirteen years indicates a general tendency to reduction in the number of unemployed in the region (by 2.8 times in 2018, as compared to 2005), the demand for workers in the labour professions is especially increasing. During the period of 2005-2018, the number of unemployed in this category has

decreased by almost 3 times (in agriculture and fishery – by 9 times), and demand for them has doubled.

Conclusion. Ternopil region was and still remains a manpower-surplus region. Its labour and resource potential is characterized by a high proportion of able-bodied persons, but a low level of employment. The main features of labour resource potential may negatively affect the development of certain sectors of the economy in the future. In the modern period, there have been positive changes in the use of labour and resource potential – increased employment in certain sectors of production, the spread of new professions, etc. This is evidence of certain positive changes in the field of economic activity, which are

Table 4. The structure of demand and supply of labour in Ternopil region for employment, persons *

	Number of registered unemployed			Demand of employers for workers to fill job workplace (vacancies)			Load on one free workplace (vacancy)		
	2005	2010	2018	2005	2010	2018	2005	2010	2018
Total	43,832	15,260	15,742	1,835	1,053	1251	24	14	13
Legislators, senior civil servants, heads, managers	2,067	1,245	1,376	99	77	89	21	16	15
Professionals	2,141	1,417	1,860	355	228	199	6	6	9
Specialists	3,183	1,476	1,718	135	84	131	24	18	13
Technical staff	1,710	777	902	39	33	40	44	24	23
Workers in the field of trade and services	3,782	1,593	2,133	129	109	213	29	15	10
Skilled workers in agriculture and forestry, fish breeding and fishing	1,809	189	193	10	6	7	181	32	28
Skilled workers with tools	4,877	2,528	2,134	446	162	276	11	16	8
Workers on maintenance, operation and control over the work of technological equipment, assembly of equipment and machinery	8,429	3,276	2,917	412	108	201	20	30	15
Unskilled occupations	15,834	2,759	2,509	210	246	95	75	11	26

* According to the data of the Main Administration of Statistics in Ternopil region

are the decrease in its quantity due to the natural reduction of the population and the migration of able-bodied persons, deterioration of the age structure of population as a result of "ageing", changes in the structure of employment in economic activity, narrowing of the professional structure of workers and imbalance in the labour market. This is the sign of exhaustion of labour and resource potential, which gradually (albeit very slowly) manifested in recent years. Availability of reserves of workforce in the labour market is the basis for further expansion of production and development of new industries. These reserves can also be used on the interregional labour market subject to its regulation. There is a fear that labour migration processes will be strengthened, that the region's labour and resource potential will be

used abroad under the conditions of establishment of a visa-free regime with EU countries. Only real social and economic reforms are a key to optimizing the use of labour resource potential in the region, regulation of supply and demand in the labour market.

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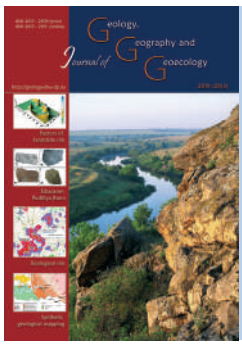

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