



Journal of Geology, Geography and Geoecology

Journal home page: geology-dnu-dp.ua

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph.
Geology,
29(2), 304–326.
doi: 10.15421/112028

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Journ. Geol. Geograph. Geoecology, 29(2), 304–326.

Researches of the chemical composition of surface water in Ukraine, 1920-2020 (review)

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Received: 04.11.2019

Received in revised form: 25.11.2020

Accepted: 27.02.2020

Abstract. The development of researches of the chemical composition of surface waters (rivers, lakes, reservoirs and ponds) is due to problems that are solved at one stage or another in the development of the country's economy and are related to water quality issues.

Depending on the tasks set during hydrochemical researches, attention is paid to a particular group of chemical components in water: 1) the main ions and their total amount (water mineralization); 2) dissolved gases; 3) biogenic elements; 4) organic matter; 5) microelements (including heavy metals); 6) radioactive elements; 7) specific pollutants. The article presents an analytical review of studies of the chemical composition of surface waters of Ukraine from the beginning of systematic research in the first half of the 20th century to the present day (1920-2020). The authors identified four typical chronological periods in the history of hydrochemical studies of surface waters in Ukraine. I period (1920s-1950s) – the beginning of systematic hydrochemical studies of surface waters; the appearance of regular observations of the chemical composition of water at the posts of hydrometeorological service on the Dnipro and Southern Bug rivers (1930s) and publication of these data in “Hydrological Yearbooks”; hydrochemical studies for selected large projects (Dnipro hydroelectric power station). II period (1950s-1970s) - expansion of hydrochemical research to meet the needs of water and hydropower construction, forecasting their possible impact on the country's water resources; increasing the number of observation points for the chemical composition of water on large and medium-sized rivers; development of hydrochemistry of reservoirs. III period (1970s – at the beginning of the 2000s) – development of complex hydrochemical researches in the conditions of increasing anthropogenic load on water objects; creation of a system of hydrochemical monitoring of water bodies within the framework of the national system of observation and control of the environment (1973); application of sanitary and hygienic criteria for assessment of water quality – universal maximum acceptable concentrations (MAC); publication of quarterly “Hydrochemical Bulletins” (since 1967); development of radioecological studies of natural waters after the Chernobyl accident (1986); first publication in Ukraine of textbooks on hydrochemistry. IV period (after the beginning of the 2000s) – reformatting of hydrochemical research (monitoring system) to the requirements of the Water Framework Directive of the European Union, especially after the signing of the EU-Ukraine Association Agreement in 2014; reforming the water monitoring system based on environmental rationing with the identification of reference indicators; components of state monitoring of surface waters are the monitoring of biological, hydromorphological, chemical and physico-chemical parameters. The article also describes scientific hydrochemical schools: Institute of Hydrobiology of NAS of Ukraine; Taras Shevchenko National University of Kyiv; Ukrainian Hydrometeorological Institute of the State Emergency Service of Ukraine and NAS of Ukraine.

Keywords: chemical composition, hydrochemical studies, surface waters, monitoring, water quality, scientific school, Ukraine

Вивчення хімічного складу поверхневих вод в Україні, 1920-2020 рр. (огляд)

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Анотація. Розвиток досліджень хімічного складу поверхневих вод (річки, озера, водосховища і ставки) зумовлюється проблемами, які вирішуються на тому чи іншому етапі розвитку економіки країни і пов'язані з питаннями якості водних ресурсів. Залежно від поставлених завдань, при гідрохімічних дослідженнях увага приділяється тим чи іншим групам хімічних компонентів, що знаходяться у воді: 1) основні іони та їхня сума (мінералізація води); 2) розчинені гази; 3) біогенні елементи; 4) органічні речовини; 5) мікроелементи (серед них важкі метали); 6) радіоактивні елементи; 7) специфічні забруднювальні речовини. У статті представлено аналітичний огляд досліджень хімічного складу поверхневих вод України

з початку систематичних досліджень у першій половині ХХ ст. і до наших днів (1920-2020 рр.). Виділено чотири характерні хронологічні періоди в історії гідрохімічних досліджень поверхневих вод на території України. I період (1920-і – 1950-і рр.) - початок систематичних гідрохімічних досліджень поверхневих вод; поява регулярних спостережень за хімічним складом води на постах гідрометслужби на річках Дніпро та Південний Буг (1930-ті рр.) і публікація цих даних в «Гідрологічних щорічниках»; гідрохімічні дослідження для окремих великих проектів (Дніпровська ГЕС). II період (1950-і – 1970-і рр.) - розширення гідрохімічних досліджень для забезпечення потреб водогосподарського та гідроенергетичного будівництва, прогнозування можливого їх впливу на водні ресурси країни; збільшення кількості пунктів спостереження за хімічним складом води на великих і середніх річках; розвиток гідрохімії водосховищ. III період (1970-і – до початку 2000-х рр.) - розвиток комплексних гідрохімічних досліджень в умовах зростаючого антропогенного навантаження на водні об'єкти; створення системи гідрохімічного моніторингу водних об'єктів в рамках загальнодержавної системи спостереження і контролю за навколишнім природним середовищем (1973 р.); застосування санітарно-гігієнічних критеріїв оцінювання якості вод – універсальних гранично допустимих концентрацій (ГДК); публікація щоквартальних «Гідрохімічних бюлетенів» (з 1967 р.); розвиток радіоекологічних досліджень природних вод після аварії на Чорнобильській АЕС (1986 р.); публікації вперше в Україні підручників з гідрохімії. IV період (після початку 2000-х рр.) - переформатування гідрохімічних досліджень (системи моніторингу) згідно вимог Водної рамкової директиви Європейського Союзу, особливо після підписання в 2014 р. угоди про асоціацію Україна-ЄС; реформування системи моніторингу вод на основі екологічного нормування з виявленням референсних показників; складовими державного моніторингу поверхневих вод є моніторинг біологічних, гідроморфологічних, хімічних і фізико-хімічних показників. В статті охарактеризовані також наукові гідрохімічні школи: Інституту гідробіології НАН України; Київського національного університету імені Тараса Шевченка; Українського гідрометеорологічного інституту ДСНС України та НАН України.

Ключові слова: хімічний склад, гідрохімічні дослідження, поверхневі води, моніторинг, якість води, наукова школа, Україна

Introduction. The chemical composition of natural waters (surface, underground and marine) is studied by hydrochemistry - the science of the chemical composition of natural waters and the laws of its changing depending on the chemical, physical and biological processes that take place in the environment. The chemical composition of natural waters largely determines their quality and the possibility of using them for water supply, irrigation, fisheries, and recreation. Nowadays, hydrochemical knowledge is important for the environmental assessment of the state of water bodies. Depending on the tasks set, during the study of the chemical composition of natural waters, attention is paid to one or another group of components in the water: 1) the main ions (HCO_3^- , SO_4^{2-} , Cl^- , Ca^{2+} , Mg^{2+} , Na^+ , K^+) and their sum (mineralization of water); 2) dissolved gases (primarily oxygen); 3) nutrients (compounds, nitrogen, phosphorus, etc.); 4) organic matter; 5) trace elements (heavy metals among them); 6) radioactive elements; 7) specific pollutants.

The development of studies of the chemical composition of surface waters (rivers, lakes, reservoirs and ponds) in Ukraine, as well as in other countries, reflects many problems that were solved at one stage or another of the country's economic development and were related to the quality of water resources used.

It should be noted that some aspects of the study of the chemical composition of surface water in Ukraine were previously covered in review articles (Denisova, Nahshina, 1974; Khilchevskiy, 2001). The same issue is also briefly addressed in the introductory part of some textbooks on hydrochemistry (Khilchevskiy et al., 2012; 2019).

One of the first scientific papers on the chemical composition of surface waters in Ukraine is the work of F.F. Kirkor "Materials on the issue of fluctuations of the composition of river water: A chemical study of the water of the Ros River 1904-1905", which was based on materials from the laboratory of the All-Russian Society of Sugar Producers (Kirkor, 1907). The researcher also made a report on this subject at the First Mendeleev Congress on General and Applied Chemistry (Department of Hygiene) in 1907 in St. Petersburg.

The beginning of systematic hydrochemical studies should be attributed to the 1920s, when the formation of the hydrometeorological service in Ukraine (1921) took place, and the works on salt lakes by B.S. Burkser (1923) appeared, the Dnipro Hydroelectric Power Station reservoir on the Dnipro River near the city of Zaporizhia began (1927). During this period, regular observations were made of the chemical composition of river waters (main ions, nutrients) at some hydrological posts of the hydrometeorological service (Dnipro and Southern Bug basins), data on which began to be published in the Hydrological Yearbooks in the 1930s. In the second half of the hundred-year period considered here, a significant number of monographic works were published on the hydrochemistry of rivers, reservoirs, the relationship of the chemical composition of various types of natural waters, reclamation hydrochemistry, methodological aspects of the study of heavy metals, and others. Among them are the works of famous Ukrainian hydrochemists like O.M. Almazov, O.I. Denysova, V.I. Peleshenko, L.M. Horiev, P.M. Lynnyk, V.I. Osadchy, V.K. Khilchevskiy and others.

Description of the problem and source materials.

The main purpose of this article is an analytical review of studies of the chemical composition of surface water in Ukraine from the beginning of systematic research in the 20 century to the present day (1920–2020). To solve this problem, published materials of Ukrainian scientists, which dealt with the issues of hydrochemistry of rivers, lakes, reservoirs, cooling basins and ponds, were used. Publications of authors of this article are also used.

Review of hydrochemical studies by periods. There are four chronological periods can be distinguished in the history of hydrochemical studies of Ukraine: I) 1920s - 1950s - the beginning of systematic studies of the chemical composition of surface waters; II) 1950s - 1970s - expansion of hydrochemical research to meet the needs of water and hydropower construction; III) 1970s - until the early 2000s - the development of integrated hydrochemical studies under conditions of increasing anthropogenic pressure on water bodies; IV) after the beginning of the 2000s - reformatting of hydrochemical studies according to the requirements of the Water Framework Directive of the European Union. This chronological division with the allocation of four periods was first proposed to research (Khilchevskiy, 2019).

The names of ministries and departments in Ukraine, as well as research institutes and universities which were engaged in hydrochemical research changed over the long considered period. Therefore, in the article, when characterizing different periods, there may be slightly different names for the same institution or department.

I period (1920s - 1950s) – the beginning of systematic hydrochemical studies of surface waters. This period is characterized by the appearance of regular hydrochemical observations on some rivers (at the hydrological posts of the hydrometeorological service on the Dnipro, Southern Bug) in Ukraine before the start of the World War II and the publication of these data in the 1930s in the “Hydrological Yearbooks” (Table 1).

The research institutions in the pre-war years were the Dnipro Biological Station in Kyiv, transformed in 1939 into the Institute of Hydrobiology of the Academy of Sciences of the Ukrainian SSR (with a department of hydrochemistry); Institute of Hydrobiology of Dnipro State University; All-Ukrainian State Black Sea-Azov Scientific and Industrial Station in Kherson; Institute of Geological Sciences, Academy of Sciences of the Ukrainian SSR; Kharkiv State University.

The organization of regular observations of the chemical composition of river waters (1938) including ions, nutrients, and mineralization of water on the

network's supervision of the hydrometeorological service became a prototype of future monitoring of water quality. These materials were subsequently used for hydrochemical generalizations throughout the entire former USSR territory (Alekin, 1950).

In the early 1920s studies of the highly mineralized waters of salt lakes and estuaries of southern Ukraine for balneological purposes began, the results of which were published in the scientific reports (Burkser, Krokos, 1923; Burkser, 1927). In the late 1920s hydrochemical studies of the estuary section of the Dnipro River are being carried out. Particular attention is paid to the regime of oxygen in water (Sheptitskiy, 1928). In the early 1930s scientists studied the hydrochemical regime of the river Dnipro and its tributaries on the site of the Dnipro reservoir in the Zaporizhia region (Husynska, 1938). We must remind here that the Dnipro hydroelectric station was put into operation in 1932 (the first turbine). Also, the hydrochemistry of the largest Dnipro tributary - Desna was studied at this period (Tsytovykh, 1936). Already at that time, scientists began to pay attention to the sanitary-hydrobiological condition of the Donbass reservoirs and the impact of the regional industrial facilities on them (Shkorbatov, 1936). In 1941, the hydrochemical features of the Dnipro floodplain ponds in the area above and below Kyiv were researched (Tovbyn, 1941).

After the World War II, researchers began to study the chemical composition of precipitation by major ions and mineralization (Burkser, Fedorova, 1949, 1955), which were carried out as a part of a general program throughout the territory of the former USSR.

II period (1950s - 1970s) – is the period of expansion of hydrochemical studies for the needs of water management and hydropower construction. A characteristic feature of the period is significant hydrochemical researching to substantiate large water management and hydropower projects: a cascade of reservoirs on the Dnipro (1950–1974); irrigation systems in the south of the country (Inhulets and others), The North Crimean canal, and others; drainage systems in Ukrainian Polesia.

In the postwar years, comprehensive hydrochemical and hydrobiological studies of water bodies were unfolding. The leading center for hydrochemical research during this period in Ukraine was the Institute of Hydrobiology of the Academy of Sciences of the Ukrainian SSR, in which the department of hydrochemistry was developed (1947). The Institute of Hydrobiology of the Academy of Sciences of the Ukrainian SSR conducts studies of surface waters by basic ions, mineralization, nutrients, gas regime

Table 1. Description of the water management situation in general and hydrochemical studies in Ukraine by chronological periods (1920 - 2020)

Period	Years	Description of the water management	Dynamics of hydrochemical research and development of the monitoring system
I period: the beginning of systematic hydrochemical studies of surface waters	1920-s - 1950-s	Creation of a hydrometeorological service in Ukraine (1921). Start of construction of the first reservoir on the Dnipro river for the Dnipro hydroelectric station in the city of Zaporizhia (1927)	The appearance of publications on hydrochemistry. The beginning of regular observations of the chemical composition of water at the hydrometeorological service posts on the Dnipro and Southern Bug rivers (1930s) and the publication of these data in the Hydrological Yearbooks. Hydrochemical studies for individual large projects (Dnipro Hydroelectric Power Station)
II period: expansion of hydro-chemical research for the needs of water and hydroenergy construction	1950-s – 1970-s	Implementation of large hydro-energy and water projects, creation of cascade of reservoirs on the Dnipro (1950-1974) and other rivers; of irrigation systems in the south of the country (Inhulets and others), The North Crimean canal, etc.; of drainage systems in Ukrainian Polesia	Research of the hydrochemical regime of the rivers on which reservoirs were built, forecasting their impact on the country's water resources. An increase in the number of observation points for the chemical composition of water on large and medium-sized rivers. Development of hydrochemistry of reservoirs (Institute of Hydrobiology of the NAS of Ukraine), hydrochemical zoning of the territory of Ukraine (for small rivers). The publication of "Hydrochemical Bulletins" (1967)
III period: development of complex hydrochemical studies under the conditions of increasing anthropogenic pressure on water bodies	1970-s – till the beginning of 2000-s	Increased water consumption and wastewater discharge. The historical maximum of water intake from water bodies in Ukraine was noted - in 1990 (35.6 km ³). Accordingly, the maximum water discharge is 20.3 km ³ . Construction of a reservoir for the Dniester hydroelectric station (1981-1987). Accident at the Chernobyl nuclear power plant (1986). Emergence of new divisions of the hydrochemical profile	Creation of a system for hydrochemical monitoring of water bodies within the framework of the OGSS (1973). Criteria for assessing the quality of water - sanitary-hygienic (MPC). There were 284 hydrochemical monitoring stations in the hydrometeorological system of Ukraine in the 1970-1980s. The "Annual data on water quality" was published for the first time. Development of radioecological studies of natural waters after the Chernobyl accident. Textbooks on hydrochemistry began to be published in Ukraine for the first time (Taras Shevchenko National University of Kyiv)
IV period: reformatting of hydrochemical studies according to the requirements of the Water Framework Directive of the European Union	After the beginning of 2000-s	During 1991-2000 Ukraine experienced a sharp decline in the economy, after which a certain rise began. Ukraine's GDP in 2000 amounted to 40% of the 1990 GDP. GDP in 2013 amounted to 70% of the GDP in 1990. Correspondingly, there are no large water management or hydropower projects. In 2013, water withdrawal amounted to 13.6 km ³ , water disposal - 7.7 km ³ . Significant reduction in the number of hydrochemical units	After 2014 (signing the Ukraine-EU Association Agreement), the water monitoring system is being reformed in accordance with the requirements of the EU WFD based on environmental regulation. State monitoring of surface waters should be carried out according to biological, hydromorphological, chemical and physico-chemical indicators. Since 2020, water monitoring should be carried out on surface water bodies, more than 9,000 of which have been allocated. Their ecological and chemical status is determined. In 2019, the hydrometeorological departments of the State Emergencies Service of Ukraine conducted hydrochemical monitoring of surface waters at 327 points and 56 sea stations; The State Water Agency of Ukraine - at 436 points

(oxygen and carbon dioxide content). The main rivers of the country were studied: the Dnipro (Almazov, 1955), the Dniester, the Southern Bug (Almazov et al., 1959) and their tributaries, reservoirs (Almazov et al., 1967), estuarine sections of rivers and estuaries of the Northern Black Sea Region (Almazov, 1960, 1962), estuaries of the northwestern part of the Black Sea (Almazov, Denisova, 1955).

During this period, significant studies were carried out on the hydrochemistry of small rivers, ponds

and small bodies of water in various natural zones of the country. In total, there are over 63 thousand rivers in Ukraine, including 8 large rivers (Dnipro, Desna, Dniester, Danube, Prypiat, Siverskyi Donets, Southern Bug, Tisza), about 20 thousand lakes, over 49 thousand ponds and more 1,100 reservoirs, among which 7 can be considered large - on the Dnipro and Dniester rivers (Vodnyi fond Ukrainy, 2015). This made it possible to develop hydrochemical zoning of the territory of Ukraine, which reflects the spatial

physical, geographical, climatic, and geological conditions for the formation of the chemical composition of water in small and medium rivers (Konenko, 1952, 1971). However, the relationship with the physical-geographical zoning is not displayed as clearly as in the case of hydrological zoning, because of the influence of local geological and soil conditions. The areas of distribution one or another hydrochemical type of water are distinguished in the hydrochemical zoning of the territory of Ukraine, and the value of their total mineralization is indicated. The main hydrochemical types of water are as follows: 1) calcium bicarbonate; 2) bicarbonate-calcium-magnesium-sodium; 3) sulfate-bicarbonate-calcium-sodium; 4) sulfate-chloride-sodium-calcium; 5) sodium chloride-sulfate.

At the same time, the water mineralization of small and medium rivers in Ukraine is growing from 200–300 mg/L to 1,500–3,000 mg/L from the northwest to the southeast - from Ukrainian Polesia to the Sea of Azov. There is a change in the hydrochemical types of river waters, that happens in the same direction, and which is confirmed by modern research (Khilchevskiy, Kurylo, Sherstyuk, 2018).

In the 1950s large-scale hydrochemical studies were carried out on the river Dnipro in connection with the beginning of construction of a cascade of Dnipro reservoirs, as well as the Inhulets irrigation system and the Northern Crimean Canal, which were supposed to receive water from the Dnipro (Tovbin et al., 1954; Denisova, Almazov, 1961; Denysova, Maistrenko, 1962). Particular attention was paid to the chemical composition of the lower reaches of the Dnipro and Inhulets rivers in order to achieve optimal mineralization of the water in the Inhulets irrigation system (built in 1952–1963) and the forecast of the hydrochemical regime of the Kakhovka reservoir, from which water should enter the Northern Crimean Canal (the canal was built in stages in 1957–1975). In total, a cascade of six reservoirs was built on the Dnipro. The list of reservoirs downstream the river is as follows: Kyiv (1964–1966); Kaniv (1974–1976); Kremenchuk (1959–1961); Kamianske (1963–1964); Dnipro (1932, 1948); Kakhovka (1955–1958). The largest among them are Kakhovka (18.2 km³) and Kremenchuk (13.5 km³).

The results of further hydrochemical studies concerning the Dnipro, its tributaries, and the created reservoirs are summarized in monographs of scientific-researchers of the Institute of Hydrobiology of the Academy of Sciences of the Ukrainian SSR (Maystrenko, 1965; Almazov et al., 1967) and in a number of articles. A complete hydrochemical characteristics of the Dnipro basin was carried out, the features of the

formation of the natural hydrochemical regime and its changes during flow regulation were established, a forecast was made regarding a possible change in the regime of the estuarine section of the river after river flow reduction due to the construction of reservoirs (Denisova, 1965, 1968, 1971; Denysova et al., 1971). Attention was paid to studies of the hydrochemical regime, ionic and biogenic runoff of the Upper Dnipro (to Kyiv), as a section of a river that is not planned to be regulated by reservoirs (Nakhshyna, 1964; Nakhshyna, 1968).

Ukrainian scientists have joined to the study of the hydrochemical regime of the transboundary river Danube (the Soviet section of the river back then). They took part in the International Program developed by the Danube countries (Almazov, Maystrenko, 1953, 1961).

Hydrochemical studies were also carried out in other institutions of the Academy of Sciences of the Ukrainian SSR, higher education institutions and research institutes. The researchers of the Institute of Hydrobiology of Dnipro State University studied the hydrochemical regime of small rivers and reservoirs in the middle Dnipro region, as well as the Dnipro and Kamianske (then Dniprodzerzhynsk) reservoirs, assessed the sanitary condition of reservoirs in the Dnipro region (Rovinskaya, Parsenyuk, 1953; Rovinskaya, 1955).

Hydrochemical regime of ponds, reservoirs and cooling ponds of thermal power plants in the Kharkiv region and Donbass was also studied at the Department of Hydrobiology of Kharkiv National University (Abremkaya, 1969; Baranov et al., 1971; Beluha, 1969; Pashkova 1956). The chemical composition of the mine waters of the Luhansk region was studied and issues of surface water protection from their influence were developed (Soboleva, Peltihin, 1962).

The issues of pollution the river Desna by industrial and domestic wastewaters were discussed, which along with the river Dnipro. Desna river is a source of drinking water in Kyiv (Nakhshyna, Almazov. 1964, Shtitelman, Almazov, 1963).

In the “Hydrological Yearbooks” published by the hydrometeorological service, the number of monitoring points with information on the chemical composition of surface waters, which was published before 1975, increased. In 1967, “Hydrochemical Bulletins” appeared, published quarterly by the hydrometeorological service, in which the number of identified chemical components was expanded covering specific pollutants (petroleum products, pesticides, some heavy metals). Observations of the chemical composition of surface waters began to be carried

out by the laboratories of the water inspection of the Ministry of Land Reclamation and Water Management of Ukraine.

The annual monitoring of the chemical composition of waters and the general condition of estuaries and salt lakes of the Black Sea region since 1953 began to be carried out by the Hydrogeological operation and maintenance station in Odesa (the works had been carried out until 1996).

III period (1970s - until the beginning of the 2000s) - the development of integrated hydrochemical studies under the conditions of an increasing anthropogenic pressure on water bodies. This period is characterized by a significant increase in water consumption, especially in industry, an increase in wastewater discharge into water bodies. The historical maximum water intake from water bodies in Ukraine was reached in 1990 - 35.6 km³. At the same time, the maximum discharge was 20.3 km³. The construction of the Dniester hydroelectric reservoir took place (1981-1987). In 1986, an accident occurred at the Chernobyl nuclear power plant.

The characteristic features of the period are the emergence of new research hydrochemical units; increased attention to water quality issues; creation of a system for hydrochemical monitoring of water bodies within the framework of the national environmental monitoring and control system in 1973; studying the consequences of radioactive contamination of natural waters caused by the accident at the Chernobyl nuclear power plant in 1986; the textbooks on hydrochemistry for higher education institutions began to be published for the first time in Ukraine.

In 1972, the United Nations Conference on the Human Environment was held in Stockholm, at which considerable attention was paid to the problem of environmental pollution by harmful substances and, accordingly, to the issue of deepening environmental monitoring. The decision to organize the National Monitoring and Control Service based on the hydrometeorological service, separated by the level of pollution of environmental objects, was made in the former USSR as the response to the conference in Stockholm. For all water bodies of the country, universal sanitary and hygienic criteria for assessing the quality of water by maximum permissible concentrations of substances are applied.

New research and production institutions are being created in Ukraine. New laboratories are also being created in existing institutions, in which hydrochemical and hydroecological applied studies are intensified. It should be noted, that with the establishment of Ukraine as an independent state (1991), many

institutions changed their names, some subsequently closed.

The following are being created: Kyiv Hydrometeorological Observatory of the Hydrometeorological Service of Ukraine with the Department for Monitoring and Control of Environmental Pollution (1973), now it is the Central Geophysical Observatory named after Boris Sreznevsky State Emergency Service of Ukraine (SES); State Water Inspection of the Ministry of Land Reclamation and Water Resources of the Ukrainian SSR with hydrochemical laboratories (1970s); All-Union Scientific Research Institute of Water Conservation of the USSR Ministry of Land Reclamation and Water Management in Kharkiv (1971), now it is the Ukrainian Scientific Research Institute of Environmental Problems; Ukrainian branch of the Central Research Institute for the Integrated Use of Water Resources of the Ministry of Land Reclamation and Water Resources of the USSR (1973), now is Ukrainian Research Institute of Water and Environmental Problems; the Department of Hydrochemistry at the "Ukrghiprovdokhoz" Institute (early 1980s), now is the "Ukrvodproekt" Institute; laboratory of hydrochemistry at the Ukrainian Research Institute of Hydrotechnics and Land Reclamation of the Ministry of Land Reclamation and Water Resources of the USSR (early 1980), now is the Institute of Water Problems and Land Reclamation of the National Academy of Agrarian Sciences of Ukraine; the Department of radiation and hydrochemical monitoring (1986), as well as the department of hydrochemistry (1996) at the Ukrainian Research Hydrometeorological Institute.

In 1971, the Faculty of Geography of Kyiv National University named after T.G. Shevchenko created a problematic research laboratory of hydrochemistry (Hilchevskiy, 2018), and in 1976 the Department of Land Hydrology was renamed in the Department of Hydrology and Hydrochemistry (Hilchevskiy, 2019).

In 1980, the hydrometeorological service, instead of the quarterly "Hydrochemical Bulletins", began to publish "Annual Data on the Quality of Surface Water on the Land" (an annual bulletin that was published before 1990). Since 1976, they stopped publishing data on the chemical composition of surface waters in the Hydrological Yearbooks.

Researchers increased attention to water quality. One of the important areas of research at All-Union Scientific Research Institute of Water Protection was the development of approaches to environmental assessments of surface water quality from a water protection position (Lozanskiy et al., 1979; Vernichenko, 1979), methods for integrated assessment of water

quality using combinatorial indices (Gurariy, Shayn, 1975). An ecological classification of watercourses of Ukraine was carried out (Vernichenko, Poddashkin, 1993).

The development of traditional topics on the hydrochemistry of reservoirs continued with the clarifying of methods for predicting changes in their hydrochemical regime (Denisova, 1979; Denisova et al., 1979), the deepening of studies of trace elements (Nahshina, 1983), forms of migration of heavy metals in fresh waters, as an integral part of ecological toxicological characteristics of aquatic ecosystems. (Linnik, Nabivanets, 1986; Linnik, 1989, 1990; Linnik et al., 1993).

It was established that, along with factors that determine the natural hydrochemical regime of the river (mainly the influence of the Upper Dnipro tributaries and the natural hydrological regime of the river), new factors have appeared that largely determine the hydrochemical regime of reservoirs and lower sections of the river. These include both an altered hydrological regime and various physical, biological processes occurring in reservoirs.

A significant influence on the hydrochemical regime of reservoirs is their cascade arrangement. The upper reservoir (Kyiv), in which the formation of the hydrochemical regime occurs under the influence of the rivers feeding it, differs from the middle ones and especially from the closing cascade of the reservoir (Kakhovka), since internal-water processes and the influence of the upper reservoirs (Denisova, 1979, 1981; Denisova et al., 1979) play the main role in the last ones.

Water quality studies of the Danube estuary were carried out in connection with the designing works at the Danube- Dnipro canal. These works were summarized in a monograph on hydroecology of the lower Danube (Harchenko et al., 1993).

The regulation of the main waterways of Ukraine and the significant withdrawal of water for irrigation and water supply necessitated the study of estuarine sections of rivers (Dnipro and Southern Bug), estuaries (Dnipro, Southern Bug, Dniester), development of a forecast of the hydrochemical regime of the Dnipro-Bug estuary (Zhuravleva, 1972, 1989, 1991) on various options for reducing the flow of the Dnipro, including the construction of a barrier dam in the area of Ochakov (in the 1980s, such a project was developed).

Scientists at the Taras Shevchenko National University of Kyiv evaluated the relationship between the chemical composition of various types of natural waters of Ukraine (precipitation, surface and groundwaters) (Peleshenko, 1975, 1980); hydrochemical

zoning of surface waters of the territory of Ukraine by hydrochemical fields was developed (Zakrevskiy et al., 1979); hydrochemical mapping methods have been developed (Peleshenko et al., 1979); probabilistic-statistical methods for processing hydrochemical information have been introduced (Peleshenko, Romas, 1977). Subsequently (1980-1995), new scientific directions appeared at the department and in the laboratory, which significantly expanded the range of hydrochemical studies (Peleshenko et al., 1989; Hilchevskiy, 2018).

The formation of the chemical composition of atmospheric precipitation in Ukraine through a network of weather stations has been studied (Romas, 1979). The theoretical and methodological foundations of ameliorative hydrochemistry, the proposed unified mathematical methods for optimizing the functioning of irrigation systems were developed. The scientific direction - hydrochemistry of irrigated lands was founded (Gorev, 1986; Gorev, Peleshenko 1984, 1988).

Based on hydrochemical studies of water bodies of Ukrainian Polesia, processes of migration and accumulation of chemical elements in natural waters in drained territories were studied (Zakrevskiy et al., 1985; Zakrevskiy, 1991, 1992; Peleshenko et al., 1978, 1980).

As a result of hydrochemical studies at the experimental water collectors of the Pridesnyansk (mixed forest zone), Boguslavsk (forest-steppe zone) and Veliko-Anadolsk (steppe) water balance stations, a methodology was developed for assessing the effect of agrochemicals on the chemical composition of natural waters. An agrohydrochemistry, the new scientific direction was founded (Hilchevskiy, 1990; Khilchevskiy, 1994; Khilchevskiy, 1995, 1996, 1996).

Methodological research approaches have been developed and a system of hydrochemical monitoring of natural waters in nuclear power plant areas have been established (Romas, 2002, 2004). The content of a number of trace elements in the natural waters of Ukraine was studied and new approaches to their determination were created (Savitskii et al., 1986; Savitskiy et al., 1994). A conceptual model has been developed to study hydrochemical systems as a complex of chemicals and processes that occur in natural waters (Snizhko, 2002, 2004).

Some generalizations concerning the flow of chemicals from the territory of Ukraine have been made (Zakrevskii et al., 1989), the anthropogenic impact on the chemical composition of river waters (Khilchevskii et al., 1994, 1999), published maps of the chemical composition of surface waters of Ukraine in

the “Hydrochemical Atlas of the USSR” (Peleshenko et al., 1990), of methods for environmental assessment of surface water quality in the relevant categories by the team of authors of the Institute of Hydrobiology of the NAS of Ukraine, the Ukrainian Research Institute of Water-Environmental Problems, approved in 1998 by the Ministry of Ecology and Natural Resources of Ukraine as a normative document (Romanenko et al., 1998) was an important step in ensuring the regulatory framework for assessing the status of water bodies. The basis of this technique is a system of environmental classifications of the surface water quality, which consists of three groups of indicators: salt composition, trophic-saprobiological (ecological-sanitary) and substances of toxic and radiation effects.

In addition to the main methodology, together with the Institute of Geography of the National Academy of Sciences of Ukraine, the “Methodology for mapping the ecological state of surface waters of Ukraine” was created (Rudenko et al., 1998).

Post-Chernobyl radiological-hydrochemical studies. A typical feature of hydrochemical studies in the 3rd period is their combination with the study of the factors and consequences of radioactive contamination of natural waters caused by the accident at the Chernobyl nuclear power plant in April 1986. This meant the start of a new type of research that can be qualified as “post-Chernobyl radiological-hydrochemical”, closely related to hydroecological and sanitary research.

Such studies aimed at constant-studying of the role of the radiation factor in the dynamics of hydroecosystems and the degree of danger caused by using water resources radioactively contaminated territories to public health.

For example, the authors of the Institute of Hydrobiology of the National Academy of Sciences of Ukraine discuss the issues of post-Chernobyl radioactive and chemical pollution of the river Dnipro and its reservoirs, primarily strontium-90 and cesium-137 (Romanenko et al., 1992), as well as the hydroecological consequences of the Chernobyl accident (Ev-tushenko et al., 1992).

The two-volume work of a team of specialists from various institutes outlines approaches to monitoring the radioactive contamination of natural waters of Ukraine (1st volume) (Voytsekhovich, 1997) and forecasting radioactive contamination of water, assessing the risks of water use and the effectiveness of water protection countermeasures for water ecosystems in the zone of influence of the Chernobyl accident (Voytsekhovich, 1998). The issues of surface water quality management in the impact zone of the

Chernobyl accident were also investigated (Voytsekhovich, 2001; Los et al., 2001).

In addition, in this direction, we can distinguish the works on the radioecology of rivers (Merezhko, 1991), reservoirs (Kuzmenko, 1998), the creation of a cadastre of radioactive contamination of local use water bodies of Ukraine (Samoilenko, 1998).

IV period (from the beginning of the 2000s) - re-formatting of hydrochemical studies according to the requirements of the EU Water Framework Directive (Directive, 2000). A typical feature of the period is a decrease in the research units of the hydrochemical profile in connection with a significant decrease in practical projects in the country.

During this period, the following areas of hydrochemical research and organizational activities related to water monitoring can be noted: 1) continuation of hydrochemical research, characteristic of scientific areas that have developed in the relevant institutions of the country; 2) due to the lack of large expeditions on research vessels along the cascade of reservoirs on the river. The Dnipro increased attention to hydrochemical studies of small water bodies in urban areas, as well as water bodies of the Black Sea region; 3) the interest to the water quality in transboundary river basins, especially those with the EU countries, is increased; 4) the beginning of the reform of the state water monitoring system in accordance with the requirements of the Water Framework Directive of the European Union, especially after 2014 (signing of the Ukraine-EU Association Agreement); 5) the emergence of studies related to climate change. We consider these areas below.

1) In general, during this period hydrochemical studies continued in Ukraine, which are typical scientific areas that have been developed in the relevant institutions of the country. Hydrochemists at the Institute of Hydrobiology of the National Academy of Sciences of Ukraine (Kyiv) have developed studies of heavy metals in river waters and bottom sediments (Linnik, Zubenko, 2000; Vasilchuk, Linnik, 2004; Linnik, et al., 2012; Linnik RP, Zubenko et al., 2012). These studies are devoted to the role of various groups of dissolved organic substances of surface waters in metal migration (Linnik, et al., 2013; Zhezheria et al., 2017), the behavior of individual metals in water, for example, aluminum, vanadium, copper, and lead (Linnik and Zhezheria, 2010; Linnik, 2014; Linnik, Linnik, 2018). Regional hydrochemical studies were also carried out (Morozova A.A., 2018).

Scientists at the Taras Shevchenko National University of Kyiv carried out regional hydrochemical studies of various river basins: assessing the effect

of sulfate karst on the chemical composition of the Dniester river water and ion removal (Aksom, Khilchevskiy, 2002; Khilchevskiy et al., 2019), studying the hydrochemical regime of the Ukrainian Polesia rivers (Kowalczyk et al., 2002), the hydrodynamics and hydrochemistry of slope watercourses (Budnik, Khilchevskiy, 2005), as well as the hydrological and hydrochemical characteristics of the minimal river flow in the Dnipro basin (Khilchevskiy, edit., 2007), an assessment of the hydroecological state of the Ros River and its water quality (Khilchevskiy, edit., 2009), Horyn River in the region of the Khmel-nitsky NPP (Khilchevskiy, edit., 2011), river Southern Bug (Khilchevskiy, edit., 2009), river Inhulets (Khilchevskiy, Kravchynskiy, Chunarov, 2012), river Dniester (Khilchevskiy, Stashuk, edit., 2013), rivers Sula, Psel, and Vorskla (Khilchevskiy, Stashuk, edit., 2014). Together with scientists from the Oles Honchar Dnipro National University, the features of hydrochemical processes in technogenic and natural reservoirs of Krivbass were studied (Sherstyuk, Khilchevskiy, 2012). Generalizations were made on the chemical composition of various types of natural waters of Ukraine (Khilchevskiy, Kurylo, Sherstyuk, 2018), as well as on the effect of the chemical composition of atmospheric precipitation on water bodies (Khilchevskiy, et al., 2019). Together with scientists from the Carpathian National Natural Park, the chemical composition of the spring water in the Ukrainian Carpathians was studied (Kravchynskiy et al., 2019).

Researchers from Ukrainian Hydrometeorological Institute created a number of hydrochemical maps for the “National Atlas of Ukraine” (Osadchyi et al., 2007). The institute also studies hydrochemical processes (Nabyvanets et al., 2007; Osadchyi, 2008; Osadchyi et al., 2008; 2013; 2016), studies the humic substances (Osadcha, 2011; Osadcha et al., 2017), and regional aspects of hydrochemical research using hydrochemical modeling.

Ukrainian Institute of Environmental Problems (Kharkiv) improved the methodology for environmental assessment of the surface water quality in the relevant categories (Hrytsenko et al., 2012), issues on environmental standardization of the surface water quality were developed taking into account regional features (Vasenko et al., 2013, 2017).

2) Due to economic problems in the country, large expeditions on research vessels on the cascade of reservoirs on the river Dnipro were ceased. Therefore, the attention to hydrochemical studies of reservoirs of urbanized and technologically congested areas as part of integrated hydroecological studies has been increased. This includes the study of the reservoirs

of Kyiv (Afanasieva, 2010; Lynnyk et al., 2015; Morozova, Diachenko, 2018), Lutsk (Zabokrytska et al., 2016), Krivbass (Sherstyuk, 2011), the development of issues on the revitalization of rivers in urban areas (Khilchevskiy, 2017). Scientists at Odesa State Environmental University have expanded research on the quality of water in the Black Sea water bodies (Hryb et al., 2019; Loboda et al., 2016).

3) It should be noted that the projects on assessment of the water quality in the basins of transboundary rivers (Tisza, Western Bug, Dnipro, Prypiat, Dniester), as well as the Southern Bug, which were funded by the European Union, were carried out in Ukraine from the early 2000s. Among a number of publications on transboundary river basins, the monographs about Dnipro can be noted - identification and assessment of the water body pollution sources (Romanenko et al., 2004), the Western Bug - water quality in Ukraine (Zabokrytska et al., 2006), Prypiat - quality management waters of the sub-basin (Aliiev et al., 2012), as well as some modern articles on the hydrochemistry of the Western Bug (Khilchevskiy, Zabokrytska, Sherstyuk, 2018; Gopchak et al., 2019), Tisza (Skoblei, Lynnyk, 2014; Linnik, Skoblei, 2018; Khilchevskiy, Leta, 2016, 2017), Danube (Klebanov, Osadcha, 2012; Nabivanets Yu.B., et al., 2016; Khilchevskiy, 2019). Scientists also developed the pilot projects for river basin management of the river Tisza (Natsionalnyi plan, 2012) and Southern Bug (Plan, 2014), which should serve as a model for drawing up formal river basin management plans.

4) In 2016, the Verkhovna Rada of Ukraine adopted the Law of Ukraine “On Amending Certain Legislative Acts of Ukraine Regarding the Implementation of Integrated Approaches in Water Resources Management on the Basin Principle”, which adopted many provisions specific to the EU WFD. Based on the previously developed methodology (Grebin et al., 2013; Khilchevskiy et al., 2019), a new hydrographic zoning of the country’s territory with 9 river basin districts was approved: Dnipro, Dniester, Danube, Southern Bug, Don, Vistula, Crimea rivers, rivers of the Black Sea, rivers of the Azov region (Zakon Ukrainy, 2016). The adopted changes are included in the Water Code of Ukraine (Vodnyi kodeks, 1995).

The “Procedure for the implementation of state water monitoring” was approved by the Decree of the Cabinet of Ministers of Ukraine of September 19, 2018 No. 758 (Postanova, 2018). The components of the state monitoring of the surface water are monitoring of biological, hydromorphological, chemical and physic-chemical indicators. Instead of a universal criterion, MPC should determine the reference values of

controlled indicators for various river basins. Since 2020, water monitoring should be carried out on the surface water bodies, of which 9.015 were allocated in Ukraine. Based on these data, the ecological and chemical status of the surface water masses will be determined, on the basis of which plans will be developed for river basin management and the level of achievement of environmental goals - higher water quality will be evaluated.

The hydrochemical monitoring system is being reformed in the same context. The list of pollutants to determine the chemical state of surface and groundwater massifs and the ecological potential of an artificial or substantially altered surface water massif were approved (Perelik, 2017). Ukrainian scientists conducted research on the analysis of the surface water quality assessment methods used in Ukraine, and identified the main tasks of their adaptation to European legislation (Osadcha et al., 2013; Yatsiuk et al., 2017).

5) The question regarding the impact of climate change on the chemical composition of the surface water in Ukraine at this stage does not yet have a clear answer. There are few publications on this subject. Thus, the studies (Khilchevskiy, Kurylo, 2014; Khilchevskiy, Kurilo, 2015) on the transformation of the chemical composition of the river waters over a long period (since the 1950s) showed a tendency towards an increase in water mineralization due to sulfate and chloride ions, especially for left-bank tributaries of Dnipro. The authors conclude that there is an influence of underground nutrition on this process. This is manifested in a decrease in the volume of surface water runoff during the spring flood, which is associated with a decrease in snow reserves in water collectors in winter due to frequent thaws. As a result, the share of underground nutrition increases at this time. As it is known, the groundwater has a large salinity, which affects the increase in salinity and content of major ions in river waters. Similar conclusions are made in the work on the hydrochemistry of the rivers Psel and Vorskla (Loboda, Pylypiuk, 2017). The authors believe that the effect of climate change on the abiotic factors of aquatic ecosystems is manifested in changes of the content and temperature regime of river water.

Another scientific research (Osadchyi, 2017) is devoted to assessing the resources and quality of the surface waters of Ukraine under anthropogenic pressure and climate change. The author concludes that the indicators of the chemical composition of the river waters, which depend on natural factors (water mineralization, humus content), have not changed over many years.

Scientific hydrochemical schools in Ukraine. During the period under review, several scientific hydrochemical schools (centers) were formed, which can be localized by institutions. Candidates and doctors of sciences who defended doctoral dissertations in hydrochemistry were also trained at these centers (Hilchevskiy, Gopchenko, Loboda et al., 2017; Greben, Zabokritskaya, 2018).

Scientific hydrochemical school of the Institute of Hydrobiology of the National Academy of Sciences of Ukraine - was formed on the basis of the department of hydrochemistry of this institute (since the 1950s). The greatest increase in research was associated with the study of the hydrochemistry of small rivers and ponds; hydrochemical features of estuarine areas of rivers; hydrochemical regime of the cascade of Dnipro reservoirs; forms of stay of heavy metals in water and bottom sediments. The employees of the Institute of Hydrobiology defended four doctoral dissertations in hydrochemistry (Table 2): hydrochemistry of the lower reaches of rivers, open estuaries and the estuary seaside of the Northern Black Sea Region (Almazov, 1960); hydrochemical regime of the Dnipro reservoirs and methods for its prediction (Denisova, 1981); forms of location and basic patterns of migration of heavy metals in the surface waters of the Ukrainian SSR (Linnik, 1990); hydrochemical regime of water bodies in contact with the sea, and the effect of hydraulic engineering construction on it (Zhuravleva, 1991).

Scientific hydrochemical school of Taras Shevchenko National University of Kyiv - was formed in the 1970s basing on the research laboratory of hydrochemistry, as well as the department of hydrology and hydrochemistry (Hilchevskiy, 2019). The main studies were devoted to: studying the relationship of the chemical composition of various types of natural land waters in Ukraine (precipitation, surface and groundwater); the impact of drainage and irrigation land improvement on the chemical composition of natural waters; hydrochemical mapping; the study of the effect of agrochemicals (primarily nitrogen and phosphorus compounds) on the quality of surface waters in experimental water collectors in various natural zones of Ukraine; assessing the impact of nuclear and thermal energy on water quality; the study of hydrochemical systems as a complex of chemicals and processes in natural waters. The specialists of Kyiv University defended six doctoral dissertations in hydrochemistry: an assessment of the relationship of the chemical composition of various types of natural land waters (assessment, balance and forecast) using the territory of Ukraine as an example (Peleshenko,

Table 2. Doctoral dissertations in hydrochemistry defended by Ukrainian scientists for the period under review (as of 2019)

No	Full name, scientist's life period, work place	Academic degree, year of defense of the dissertation	Topic of the doctoral dissertation	Code, scientific specialty	Institution where the defense took place
1	Almazov Oleksandr Markovych (1912-1966), Institute of Hydrobiology, Academy of Science of UkrSSR	Doctor of Geographical Sciences, 1960	Hydrochemistry of the lower reaches of rivers, open estuaries and pre-estuary seaside (Northern Black Sea Coast)	* land hydrology	Lomonosov Moscow State University, Moscow
2	Peleshenko Vasyl Ilarionovych (1927-2014), Taras Shevchenko National University of Kyiv	Doctor of Geographical Sciences, 1981	Assessing the relationship of the chemical composition of various types of natural land waters (assessment, balance and forecast by the example of the territory of Ukraine)	11.00.10** - hydrochemistry	Hydrochemical Institute, Rostov-on-Don
3	Denysova Oleksandra Ivaniivna (1924-2005), Institute of Hydrobiology, Academy of Science of UkrSSR	Doctor of Geographical Sciences, 1982	Hydrochemical regime of the Dnipro reservoirs and methods for its prediction	11.00.10 - hydrochemistry	Hydrochemical Institute, Rostov-on-Don
4	Horiev Leonid Mykolaiovych (1939-1999), Taras Shevchenko National University of Kyiv	Doctor of Geographical Sciences, 1987	Theoretical and methodological foundations of the hydrochemistry of irrigated land	11.00.10 – hydro-chemistry	Hydrochemical Institute, Rostov-on-Don
5	Zhuravlova Lidiia Olekciivna (1932-2001), Institute of Hydrobiology, Academy of Science of UkrSSR	Doctor of Geographical Sciences, 1991	Regularities of the formation of the hydrochemical regime of certain types of water bodies in contact with the sea and its changes under the influence of hydraulic engineering construction	11.00.07 - *** land hydrology, water resources, hydrochemistry	Hydrochemical Institute, Rostov-on-Don
6	Lynnyk Petro Mykytovych (1952), Institute of Hydrobiology Academy of Science of UkrSSR	Doctor of Chemical Sciences, 1991	Forms of research and basic patterns of migration of priority heavy metals in surface waters of land (on the example of water bodies of Ukraine)	11.00.11 - environmental protection	D. Mendeleev Institute of Chemical Technology of Russia, Moscow
7	Zakrevskiy Dmytro Vasylovych, (1929-2006) Taras Shevchenko National University of Kyiv	Doctor of Geographical Sciences, 1992	Hydrochemistry of drained lands (in the Northern-Western conditions of Ukraine)	11.00.07 - land hydrology, water resources, hydro-chemistry	Hydrochemical Institute, Rostov-on-Don
8	Khilchevskiy Valentyn Kyrylovych (1953), Taras Shevchenko National University of Kyiv	Doctor of Geographical Sciences, 1996	Assessment of the influence of agrochemicals on the runoff of chemical substances and the quality of surface waters (on the example of the Dnipro basin)	11.00.07 - land hydrology, water resources, hydro-chemistry	Taras Shevchenko National University of Kyiv, Kyiv
9	Snizhko Serhii Ivanovych (1958), Taras Shevchenko National University of Kyiv	Doctor of Geographical Sciences, 2002	Theory and methods of analysis of regional hydrochemical systems	11.00.07 - land hydrology, water resources, hydro-chemistry	Taras Shevchenko National University of Kyiv, Kyiv
10	Romas Mykola Ivanovych (1943-2009), Taras Shevchenko National University of Kyiv	Doctor of Geographical Sciences, 2004	Hydrochemistry of of nuclear and thermal energy water bodies	11.00.07 - land hydrology, water resources, hydro-chemistry	Taras Shevchenko National University of Kyiv, Kyiv
11	Osadchy Volodymyr Ivanovych (1955), Ukrainian Hydrometeorological Institute of the State Emergency Service	Doctor of Geographical Sciences, 2008	Methodological foundations of the study of factors and processes of the formation of the chemical composition of surface waters	11.00.07 - land hydrology, water resources, hydro-chemistry	Taras Shevchenko National University of Kyiv, Kyiv
12	Osadcha Nataliia Mykolaivna (1959), Ukrainian Hydrometeorological Institute of the State Emergency Service	Doctor of Geographical Sciences, 2011	Patterns of migration of humic substances in surface waters of Ukraine	11.00.07 - land hydrology, water resources, hydro-chemistry	Taras Shevchenko National University of Kyiv, Kyiv
13	Sherstyuk Nataliia Petrivna (1962), Oles Honchar Dnipro National University	Doctor of Geographical Sciences, 2013	Hydrochemistry of water bodies of iron ore basins (on the example of the Kryvyi Rih- Kremenchuk iron ore area)	11.00.07 - land hydrology, water resources, hydro-chemistry	Odesa State Environmental University, Odesa

Notes: * - code and the exact name of the scientific specialty of Almazov are not established; ** 11.00.10 - code and name of the scientific specialty “hydrochemistry” was adopted by the Higher Attestation Commission (HAC) of the former USSR in 1981-1987; *** 11.00.07 - code and name of the scientific specialty «land hydrology, water resources, hydrochemistry», was adopted since 1988 in the Higher Attestation Commission of the former USSR, and transferred to the nomenclature of specialties of the Higher Attestation Commission of Ukraine, created in 1992.

1980); theoretical and methodological foundations of hydrochemistry of irrigated lands (Gorev, 1986); hydrochemistry of drained lands in the north-west of Ukraine (Zakrevskiy, 1992); assessment of the impact of agrochemicals on the flow of chemicals and surface water quality in the Dnipro basin (Khilchevskiy, 1996); theory and methods of analysis of regional hydrochemical systems (Snizhko, 2002); hydrochemistry of water bodies of nuclear and thermal energy (Romas, 2004).

Textbooks and tutorials in hydrochemistry, which used the results of scientific research, were also developed at the scientific hydrochemical school of Kyiv University. Textbooks have been published on: the basics of reclamation hydrochemistry (Gorev, 1991); hydrochemistry of Ukraine (Horiev, Peleshenko, Khilchevskiy, 1995); general hydrochemistry (Peleshenko, Khilchevskiy, 1997); hydroecological aspects of water supply and sanitation (Khilchevskiy, 1999); assessment and prediction of natural water quality (Snizhko, 2001); the basics of hydrochemistry (Khilchevskiy, Osadchyi, Kurylo, 2012); regional hydrochemistry of Ukraine (Khilchevskiy, Osadchyi, Kurylo, 2019).

The Scientific Hydrochemical School of Ukrainian Hydrometeorological Institute of the State Emergencies Service of Ukraine and the NAS of Ukraine - was formed on the basis of the Department of Regional Hydrochemistry in the 2000s. The staff of Ukrainian Hydrometeorological Institute defended two doctoral dissertations in hydrochemistry: methodological foundations of the study of factors and processes of formation of the chemical composition of surface waters of Ukraine (Osadchyi, 2008); studies of the migration of humic substances in the surface waters of Ukraine (Osadcha, 2011). Based on regional hydrochemical studies (Zabokrytska et al., 2006; U Khan, Osadchyi, 2010; Luzovitska Yu.A., et al., 2011; Klebanov, Osadcha, 2012), the development of issues of hydrochemical modeling (Osipov, Osadchaya, 2017) was prepared a number of candidate dissertations.

It should be noted that Ukrainian scientists are also engaged in research on the chemical composition and other types of water. In particular, the chemical composition of groundwater, including mineral water, is studied at the Institute of Geological Sciences of the National Academy of Sciences of Ukraine (Shes-

topalov et al., 2003; 2019). The Institute of Colloid and Water Chemistry of the National Academy of Sciences of Ukraine is developing new technologies for the purification and disinfection of drinking water and wastewater (Goncharuk, 2010; Goncharuk et al., 2006). The Ukrainian Research Institute of Medical Rehabilitation and Balneology is engaged in the study of mineral waters and peloids for balneology. Occasionally, the problems of hydrochemistry of estuarine areas of rivers are studied at the Institute of Marine Biology of the National Academy of Sciences of Ukraine (Garkavaya et al., 2008). However, these researches are a topic for another study.

Works awarded by the State Prize of Ukraine. In 1972, six hydrochemical scientists from the Institute of Hydrobiology of the Academy of Sciences of the Ukrainian SSR were awarded with the State Prize of the Ukrainian SSR for the series of scientific works “*Hydrochemistry of Surface Water of Ukraine*” (Postanova, 1972). The team of authors included: Olexandr Almazov, Masha Feldman, Yuriy Maystrenko, Olena Nakhshyna, Olexandra Denysova, Hanna Konenko.

In 2017, eight leading Ukrainian scientists from various institutions were awarded with the State Prize of Ukraine in the field of science and technology for a series of scientific papers of a hydrochemical and hydroecological nature “*Assessment, Forecasting and Optimization of the State of Water Ecosystems of Ukraine*” (Ukaz, 2018; Zabokrytska, 2018). The team of authors includes: Volodymyr Osadchyi, Yuriy Nabyvanets (Ukrainian Hydrometeorological Institute of the State Emergencies Service of Ukraine and the NAS of Ukraine), Valentyn Khilchevskiy (Taras Shevchenko National University of Kyiv), Petro Lynnyk, Oleksandr Protasov and Volodymyr Shcherbak (Institute of Hydrobiology of the NAS of Ukraine), Yevhenii Nykyforovych (Institute of Hydromechanics of the NAS of Ukraine), Borys Kornilovych (NTUU “Igor Sikorskyi Kyiv Polytechnic Institute”). The first four authors in this team are hydrochemists.

Conclusions.

1. Hydrochemical studies in Ukraine can be effectively considered in the context of the proposed four chronological periods: I) 1920s - 1950s. - the beginning of systematic studies of the chemical composition of surface waters; II) 1950s - 1970s - expansion of hydrochemical research to meet the needs of water and hydropower construction; III) 1970s -

until the beginning of the 2000s - the development of integrated hydrochemical studies under conditions of increasing anthropogenic pressure on water bodies; IV) after the beginning of the 2000s. - reformatting of hydrochemical studies according to the requirements of the EU WFD.

2. In Ukraine, for the considered period, quite serious methodological and regional studies of the chemical composition of surface waters on the main ions, nutrients, and trace elements have been developed.

3. The country has developed scientific hydrochemical schools - at the Institute of Hydrobiology of the National Academy of Sciences of Ukraine, Taras Shevchenko National University of Kyiv, Ukrainian Hydrometeorological Institute of the State Emergencies Service of Ukraine and the National Academy of Sciences of Ukraine.

4. It is noted that hydrochemical research were mostly developed in the third period (until the beginning of the 1990s), by the reason of significant water and hydropower construction.

5. In the modern IV period (since the early 2000s), the reforming of the system of hydrochemical monitoring in Ukraine takes place in accordance with the requirements of the EU WFD.

6. Along with reformatting of the water monitoring to solve the water management tasks, it is necessary to maintain water monitoring of an ecological nature, which has long series of observations and allows solving scientific and practical problems related to the study of the transformation of the chemical composition of the water over a long period of time.

7. In the short term, the tasks of hydrochemical research of the surface waters in Ukraine lie in the plane of achieving one of the UN global goals in the field of sustainable development related to ensuring the availability and sustainable management of water resources and sanitation. At the same time, issues of a possible impact of the climate change on the transformation of the water chemical composition should be taken into account.

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