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THE HYDROCHEMICAL CHARACTERISTICS OF THE LAKES OF THE SHATSK NATIONAL NATURE RESERVE

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The hydrochemical characteristics of the lakes in the Shatsk National Nature Reserve (in Polyssia, Volyn Oblast, Ukraine) are examined. With respect to the hydrocarbon and calcium ionic content of the lake waters, the ionic salinity is mainly determined by physical and geographical attributes and reflects the nature of the lithology and soil in the area. As far as the proportions of its components are concerned, the water in most of the lakes corresponds to drinking-water standards. The factors which have a bearing on the hydrochemical condition of the water are the nature of the underground water sources, as well as water from atmospheric precipitation and from soil runoff. Basic proposals are made for taking water protection measures, in order to promote the preservation and even the improvement of water quality.

Рассмотрены гидрохимические особенности озер Шацкого национального природного парка (Волынское Полесье Украины). Озерные воды за составом основных ионов относятся к гидрокарбонатно-кальциевым, ионно-солевой состав воды в них обусловлен преимущественно физико-географическими особенностями и отражают характер литологии и почв территории. Определяющим фактором формирования гидрохимического режима является связь с подземными водами, а также атмосферные осадки и грунтовые воды. Сформулированы основные положения о водоохранных мероприятиях, проведение которых будет способствовать сохранению и улучшению качества воды.

The typological changes in the conditions of these lakes has an effect on the interconnected physics-, chemistry- and biology-related indicators. In reservoirs, the impact of environmental abuse on chemical and biological indicators is particularly perceptible, and for this precise reason they are used for the study of questions related to anthropogenic changes in the lakes.

These lakes are located within densely-populated regions in which intensive factors of the rural and recreational economy are leading to an increasing level of anthropogenic influence. This involves both the [subterranean] water sources and the pollution originating throughout the watershed. This all points to the need for a comprehensive study of the reservoirs under circumstances of increasing eutrophication, in order to determine the principal reasons for the changes in water quality in the exploitation process and to develop scientifically-based recommendations regarding the rate of eutrophication and the deterioration of the sanitary state of reservoirs.

The tasks to be undertaken by hydrochemical science include assessing the quality of different types of natural waters in order to determine their suitableness for use in specific industries, for drinking water, and for public recreation facilities; but in particular it needs to provide proper conditions for the maintenance of water ecosystems.

Parallel to this function of evaluating water quality, hydrochemical methods of predicting long-term and short-term changes in the quality and the chemical composition of water have significant practical and theoretical value. The capacity to accurately predict changes in the quality of water resources is the foundation of the national and regional program for the development of the rational usage of water resources, within the broader context of the national sustainable development strategy.

Possessing data acquired during a long period of observation of the chemical composition of natural waters in the Shatsk lakes district makes it possible to draw some conclusions about the effect of climatic factors on specific water quality components, and to select the ones that are affected by anthropogenic factors and to take them into account.

The hydrochemical composition of the water mass of the lakes in Polyssia has been studied in various seasons of the year over a long period of time – [2] – but unfortunately, the results of these observations are so diverse in their values and inconsistent in their frames of reference that they are difficult to compare.

Observations of water conditions in the Shatsk National Nature Reserve (SNNR) have been made over a period of 35 years, beginning in 1972. Data sources used for the evaluation of the hydrochemical condition of the lakes include the holdings of the SNNR, the Kovel hydrological land improvement expedition, the Volyn Regional Administration for Environmental Safety, the Kyiv geological survey expedition, and the Institute of Hydraulic Engineering and Land Reclamation of the Ukrainian Agrarian Academy of Sciences.

Although the pattern of observation of the natural waters within this period was not uninterrupted, the sets of observed data included years with varying amounts of precipitation, and varying degrees of anthropogenic loading in the area under consideration.

The SNNR territory is located within the catchment areas of the Western Buh (Baltic Sea watershed) and the Prypyat (Black Sea watershed). The present-day SNNR covers an area of 49977 hectares. Within the park territory there are 24 lakes, with a total surface area of 6453.6 hectares (12.7 % of the park territory). These lakes constitute the sole water system.

Lakes Svityaz, Pulemetske and Krymno are karstic by origin; the Pisochne, Lyutsymyr and Peremut are related to a type of chalk formation with a certain karstic content having residual geological cavities, and the Chorne Velyke, related to lakes of glacial origin, which is borne out by the moraine layer on the lake bed. Among the geologically lowered areas, there are lakes of ancient origin such as the Ozertse. Their banks are peat-filled and the lakebeds are silted. Lakes of this type become highly overgrown and turn into bogs.

Almost all the lakes in the SNNR are of slow drainage. In every lake, after rising in the spring, the level returns to that of winter. A distinctive feature of the region under investigation is the fact that it is practically unconnected with the surface catchment areas of the rivers which border it – the Prypyat and the Western Bug, and its water resources are made up of local sources composed of atmospheric precipitation and partially from the flow of water from marly-chalk deposits, which are originally fed from outside the territory of the SNNR.

Most of the lakes in the Shatsk group are connected with each other by the ancient lowland cavities. Along the valley of the Prypyat, located at a higher elevation than the lakes, the underground streams and surface water are partially drawn off and taken into the catchment area of the Dnipro.

The lakes of Ukraine's Polyssia are categorized as freshwater lakes, with a mineralization that varies from 87.7 to 457 mg/dm^3 [2]. The majority of the lakes fall into the category of slightly mineralized (200–250 mg/dm^3). The basic mineralized constituents are HCO_{3-} and Ca^{2+} ions. The absolute and relative content of other ions is significantly lower. Although there are seasonal changes in the ion content in the lakes, their proportions within each lake remain practically constant, changing only occasionally due to the carbonate balance, and in locations where there is a more highly-mineralizing inflow, increasing the content of Mg^{2+}, Na^+, K^+ and SO_4^{2-}. Other mineralization indicators, such as Cl^-, are found in small amounts, and increase due to contaminated material entering the lakes. The hydrochemical characteristics of the different types of lakes in the SNNR are presented in Table 1.

Table 1 – *Hydrochemical indices of waters in the lakes of the Shatsk National Nature Reserve during the period 1972–2002*

Name of lake	Mineralization, mg/dm^3	Components, mg/dm^3 (min-max)					pH water
		Cl^-	SO_4^{2-}	NH_4^+	NO_{3-}	NO_{2-}	
Crymno	208–449	16–61	4.5–69	0.1–3.68	0.0–0.51	0.0–0.7	7.39–8.65
Lyutsymyr	154–618	2.3–39	0.77–32.0	0.0–7.0	0.1–3.2	0.0–1.4	6.6–8.25
Luky-Peremut	136–304	0.0–33	0.0–74	0.0–1.32	0.0–1.4	0.0–0.11	7.06–8.07
Svityaz	68–540	0.0–88	0.0–329.8	0.0–3.3	0.0–6.1	0.0–4.82	6.6–8.55
Chorne Velyke	251–968	17–72	2–61	0.0–21	0.0–17	0.0–0.6	5.5–8.3
Pysochne	91–266	0.08–38.1	0.0–129	0.0–5.4	0.0–3.7	0.0–0.3	6.46–8.37
Pulemetske	156–431	7.0–19.3	0.0–60.2	0.0–1.1	0.0–1.2	0.0–0.1	6.9–8.2
Ostriv'yanske	200.0–211.0	10.4–10.6	96.7–105.7	0.50–0.64	0.18–0.24	0.01–0.10	7.0–7.6
Somynets	214–379	7.8–42.0	61.3–96.8	0.1–0.61	0.11–0.17	0.04–0.06	7.1–5.5
Karasynets	98.5–213.0	7.2–28.4	73.2–103.7	0.0–0.61	0.11–0.16	0.01–0.03	7.4–7.7
Ozertse	194–289	6.4–26.7	81.8–112.3	0.0–0.32	0.10–0.16	0.05–0.08	7.7–7.9

The lake waters, on the basis of the classification of the calcification-related basic ionic composition made by O. A. Alokyn [1], are in the hydrocarbonate-calcium category (hydrocarbonate class of the calcium group C^{Ca}_{II}). Investigations

into the hydrochemistry of the lakes in the SNNR show that the composition of their waters is affected mainly by physics-related geographical factors and reflect the nature of the lithology and the soils of the area. The marlacious chalk varieties of western Ukraine's Polyssia are the main source of the alkaline ionic composition of subterranean waters, and determine the precise hydrocarbonate-calcium composition of water in the lakes.

In general the water of the lakes in the Shatsk group is fresh or ultrafresh, with moderate mineralization in all the lakes; it does not exceed 0.325 mg/dm^3. The most highly-mineralized water is in the Chorne Velyke, and the least, in the Moshne. The most significant among them are the Svityaz, Pisochne and Chorne Velyke, representing the three basic patterns of lowest, moderate and highest mineralization of waters. The currently-available volume of data makes it possible to draw verifiable conclusions about the nature of the formation of their hydrochemical condition.

In all the lakes, the chemical composition is dominated by hydrocarbonates and calcium. The amount of sulfate and chlorine ions in the water is insignificant. The amount of Cl^- is a particularly important indicator, since an increase in it is usually associated with domestic pollution. In the lakes of the Shatsk group, these components very rarely exceeded a proportion of 50 mg/dm^3, which is even below the maximum amount permitted for drinking water. Only in the water of the Chorne Velyke is the amount of Cl^- a bit higher than in the other lakes, but even there it is insignificant – up to a maximum of 72 mg/dm^3.

The data referred to above demonstrate that over the whole period of observation of the chemical composition in the Shatsk group of lakes, their water had a consistent chemical composition, with low mineralization and a low concentration of basic components. It is true that the level of nitrite ions sometimes rises to 6.1 mg/dm^3 (the Chorne Velyke, in 1996), but for the most part the values are in the range of 0 to 0.01 mg/dm^3. Although the amount of nitrate ions is higher, up to 10 mg/dm^3 (Svityaz, in 1996), which can be explained by their chemical properties, this did not exceed the maximum allowed concentration (45 mg/dm^3) for waters to have a potable classification.

Of greater informative value for determining the extent of organic pollution are the data regarding the amount of ammonia present, the maximum readings for which were obtained in waters from the Chorne Velyke in the winter of 1996 – 20 mg/dm^3. In the other lakes, the concentration of ammonia does not exceed 7 mg/dm^3. The higher level of contamination in the Chorne Velyke is connected with the release of municipal effluent from Shatsk into the lake, which was only halted in the spring of 2002. In all the lakes of the Shatsk group, the Chorne Velyke has consistently had greater permanganate oxidizability (24.2 to 43 mg/dm^3) and a higher degree of biological consumption of oxygen (BCO_5 is from 3.2 to 10.4 mg/dm^3). In the majority of readings relative to the permanganate oxidizability index, the water in the lakes does not meet the requirements of the maximum permitted concentration for waters classed for drinking purposes (4 mg/dm^3).

The chemical composition of the water in the lakes is in keeping with the origin of these waters to a definite extent. Although the Moshno, a lake of flood-plain origin, has waters with a chemical composition identical to those in the other lakes, it is characterized by a considerably lower level of mineralization than lakes of karstic or glacial origin. The karstic lakes, which are fed by artesian wells, have ordinary chemical composition characteristics, of which the predominant components are

HCO^- and Ca^{2+}. However, the mineralization of their waters is lower than in those of the artesian category, caused by the influence of atmospheric precipitates and, to some extent, topsoil runoff water.

In addition to the mineral compounds, an important part of the chemical composition of the water in the lakes consists of biogenic and organic compounds. Compounds of phosphorus and nitrogen, as well as of iron and silicon, are the principal compounds in the biogenic category. The amounts in which they are present determine the degree to which vegetation develops in the water. In deep and pure lakes their amounts are insignificant, but when these indices rise to a level of 2.65 mg/dm^3 NT, 0.194 mg/dm^3 PT (the Klymovske), the overgrowth and silting of the reservoirs begins to occur (Table 2).

The quantification of phosphorus-containing compounds in the lakes was conducted systematically from the point at which the Kopaiv catchment system begins to have an effect upon them. Throughout the whole observation period, instances of PO_4^{2-} valid for one occasion occurred only in the Luky-Peremut (1.1 mg/dm^3) and the Krymne (0.8 mg/dm^3), as the stabilized data of this index is below 0.01 mg/dm^3.

The external signs indicating the condition of a reservoir are the transparency of the water and its colour level, which indicates the amount of organic components and sediment present in it. The greatest transparency can be observed in the deep lakes, where it is up to 4.2 m (the Svityaz and the Pysochne); the colour level index is an insignificant 7–13º. The least transparent (0.4 m) are the shallow and polluted lakes with a high colour level index (Table 2).

Table 2 – *Biogenic elements, transparency and colour levels in lakes of different types*

Lake	Transparency, m	Colour level index, º	Total –N, mg/dm^3	Total – P, mg/dm^3
Svityaz	4.2	7	0.63	0.027
Pysochne	4.2	10	0.41	0.028
Peremut	4.3	13	0.68	0.035
Pulemetske	0.9	16	0.87	0.060
Lyutsymyr	1.0	22	0.88	0.079
Krymno	1.5	36	0.65	0.065
Luky	0.8	36	0.76	0.043
Ostriv'yanske	1.3	38	1.01	0.064
Ozertse	2.8	37	0.56	0.030
Krugle	0.3	38	0.67	0.32
Dovge	2.6	45	0.73	0.054
Plotychya	1.1	39	0.75	0.054
Chorne Male	1.1	42	0.93	0.028
Zvedenca	1.4	38	1.03	0.154
Moshno	1.0	52	0.83	0.057
Karasynets	1.3	37	0.75	0.032
Somynets	1.5	74	0.97	0.046
Chorne Velyke	0.4	40	1.07	0.076
Klymovske	0.4	69	2.65	0.194
Lynovets	0.9	50	1.1	0.134

The pH value [hydrogen ion concentration] of water serves as one of the major hydrochemical indices with regard to water bodies, and in a broad sense shows the quantity and quality of organic and mineral compounds, as well as gases, which characterize the water. In the lakes of the SNNR, pH values vary over a considerable range.

Changes which occur in the hydrochemical conditions of the lake systems during the regulation of their flow has a determining influence on their characteristics. The main factors here are the rate of flow and the intensity of the water cycle, and in connection with this, the intensification of the sedimentation processes; the decrease of runoff specific gravity in forming hydrochemical conditions; an increase in the role of lake-bottom deposits and the processes flowing in the boundary layer; the intensification of processes within the reservoirs, and the increase in bioproductivity; changes in the gas conditions, the qualitative and quantitative composition of the organic components, etc.

The forming of the hydrochemical conditions in the lakes takes place under the influence of external factors and internal processes within the reservoirs. The former factors are associated with the catchment basin of the rivers which feed the lakes, with the nature of the soils and the vegetation in the storage basin, with dry and moist atmospheric precipitates, and with anthropogenic factors. Its role begins with the process of the altered catchment basin of the river, when the conditions of the natural waterway change. Anthropogenic factors are involved with the water flowing from the drainage basin, and the industrial, commercial and domestic effluent which gets into the watershed.

The role and the relative importance of each of the sources mentioned above are specific to each lake; to a significant extent they are determined by soil and climatic conditions, and by the degree of industrial and agricultural development which exists within the area of the storage basin.

All in all, the hydrochemical conditions of the lakes in the SNNR are of a stable nature. The main component in the formation of the hydrochemical condition of the lakes is their direct or indirect connection with waters of artesian origin, as well as with atmosphere precipitates and soil runoff water.

On the basis of the materials referred to above and the results gained by observations made over the course of many years, it is possible to formulate some basic proposals for water-protection measures the implementation of which will be instrumental in the preservation and improvement of water quality in the SNNR lakes. It is possible to number amongst these proposals:

– the creation of shoreline water protection areas, which would decrease the size of the catchment zone from which biogenic chemical elements can flow into the storage basin;

– decreasing the harmful effects of lake-bottom deposits on the quality of the waters by the aeration of the low-lying layers of water and the periodic removal of soil deposits from the lake bottoms.

– the total elimination of all heavy metals, biogenic and organic matter from industrial, commercial and domestic effluent.

– changing the agricultural technology of utilizing mineral fertilizers and pesticides, in order to reduce their flow into the reservoirs.

– increased environmental supervision of recreational and tourism activities.

This analysis and the results which it points to are needed in order to solve the problems in the SNNR, the restoration of natural conditions in the bog complexes, and the further development in the everyday social and recreational spheres, among others. The conclusions reached can be extrapolated for other reservoirs in Ukraine's Polyssia.

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