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Article

The influence of hydrological and meteorological factors on the water quality of the Novosibirsk reservoir in the years of mean water content

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Abstract. The influence of hydrological and meteorological factors (water temperature, precipitation, intensity of external water exchange, water inflow into the reservoir, discharge to the downstream, water level, reservoir volume) on the chemical composition of water (content of dissolved oxygen, suspended solids, nitrates, nitrites, compounds containing ammonium nitrogen, sulfates, chlorides, phosphates, a number of organic substances and heavy metals) of Novosibirsk Reservoir in the mean-water years was analyzed. The period of reservoir filling in spring and the period of water level standing at the normal maximum operating level in summer were investigated as the times most important for water quality and biota development in the reservoir.

Keywords: mean-water years, hydrochemical characteristics, external water exchange, precipitation, temperature

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Научная статья

Влияние гидрологических и метеорологических факторов на качество воды Новосибирского водохранилища в годы средней водности

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Аннотация. Установлено влияние гидрологических и метеорологических факторов (температуры воды, атмосферных осадков, притока воды в водохранилище, сбросов в нижний бьеф, уровня и объема водохранилища, интенсивности внешнего водообмена) на химический состав воды (содержание растворенного кислорода, взвешенных веществ, нитратов, нитритов, соединений, содержащих аммонийный азот, сульфатов, хлоридов, фосфатов, ряда органических веществ и тяжелых металлов) Новосибирского водохранилища в средние по водности годы. Рассмотрены периоды весеннего наполнения водохранилища и летней стабилизации уровня воды на отметке нормального подпорного уровня как периоды формирования качества воды водохранилища и наиболее активного развития биоты.

Ключевые слова: средневодные годы, гидрохимические характеристики, внешний водообмен, атмосферные осадки, температура

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Introduction

The construction of large hydraulic systems is the cause of a number of large-scale changes in the natural environment. Compared to natural conditions artificial reservoirs show reduction in flow rate, water exchange, water turbulence, and develop environment promoting the appearance of stagnant zones. The lower the water exchange, the lower is the dynamics of the physical and chemical properties of water in reservoirs. A decrease in flow rates leads to disruption of the flow of suspended particles and a decrease in their content in the water. In the summer–autumn period, water aeration improves and the intensity of self-purification processes increases due to the large area of water surface (Atavin et al., 1997; Matarzin, 2003). On the other hand, autochthonous organic matter is more intensively formed resulting from a significant increase in biological production as a result of the influx of suspended sediments, dissolved substances containing nutrients and organic compounds and an increase in the average annual temperature of water masses in the reservoir, i.e. when favorable conditions for eutrophication are created (Avakian et al., 1987; Nazari-Sharabian and Taheriyoun, 2022; Wang et al., 2022).

The rate and nature of environmental conditions depend on the volume of the reservoir, its hydrological regime and the intensity of water and biological resources management.

The water quality in reservoirs is influenced by local natural conditions, meteorological factors, the degree of eutrophication and pollution of the river on which the reservoir is formed, limnological features, quantitative indicators of external water exchange, hydrodynamics and hydrophysical properties of the water mass (Lecomte et al., 2022; Li et al., 2021; Nikanorov and Posokhov, 1985; Salnikov and Sappo, 2005; Timchenko, 2006; Wang, et al., 2023).

In reservoirs, the interaction of the hydrosphere, atmosphere and aquatic biota that developed in the original river ecosystem is profoundly changed. Regulation of the hydrological regime occurs through the artificial control, which for the most part determines the functioning of the reservoir, including its hydrochemical component. The urgency for competent regulation of the hydrodynamic regime is especially high, since the increasing technogenic impact on the ecosystem reduces the self-cleaning capacity of reservoirs (Alekin, 1970; Calijuri et al., 2015; da Rocha et al., 2015; Li et al., 2021; Rosenberg et al., 2011; Setegn, 2015).

Long-term changes in the hydrological and hydrochemical regime of the Novosibirsk reservoir and its downstream regions can be as example of the generation of water quality in a large natural-technogenic system (Chaikina, 1975; Dvurechenskaya and Yermolaeva, 2014; Lanbina and Karpeeva, 1985; Podlipsky, 1985; Savkin and Dvurechenskaya, 2014; Savkin et al., 2014, 2018; Vasiliev et al., 1990, 1997).

At present time, the reservoir ecosystem has found itself both under anthropogenic pressure and from complex of natural factors (Savkin, 2000; Savkin and Dvurechenskaya, 2018). The chemical composition of water in the Novosibirsk reservoir is formed mainly due to the inflow of the Ob River. Intake of chemicals with the Ob River water is predominant in the balance sheet account (93–95%). The largest lateral tributaries do not make any significant contribution to the water quality of the reservoir (no more than 4%). At the same time, they themselves may be subjected to increased environmental stress, mainly due to the contribution of the anthropogenic factors (Dvurechenskaya, 2012).

Water quality in reservoirs depends not only on the amount of pollutants supplied by the rivers, but also on the intensity of water exchange, water temperature, amount of precipitation, etc. As a result of the regulation of water flow by reservoirs, the flow of chemicals is also regulated (Han et al., 2018; Lecomte et al., 2022; Znamensky, 1981).

Thus, the study of water quality in reservoirs and the influence of various natural and anthropogenic factors on it is a very important and urgent task.

The object of this paper is to study the influence of hydrological and meteorological factors on the chemical composition of the water of the Novosibirsk reservoir in years of mean water content, during period of the reservoir filling, and during the summer period of standing at the normal operating water level; that is during the time of forming of the water quality of the reservoir and the time of the most active development of its biota.

Materials and methods

The work was carried out a study of the interaction between water quality of the Novosibirsk reservoir and hydrological and meteorological characteristics for years of mean water level (1990, 1992, 1994, 1999, 2000, 2002, 2005, 2007 and 2009).

Water samples were taken at the agreed sites in the upper, middle and lower parts of the reservoir (Fig. 1) using a Molchanov bathometer from a vessel at a depth of 0.6 h, where h is the depth of the reservoir at the sampling point. Water temperature was measured simultaneously with sampling.

The periods of spring filling of the reservoir and summer stabilization of water level at the normal maximum operating level have been considered. There are the forming of water quality in the reservoir and the most active development of biota just during these periods.

Samples were taken during the period of open water from April to August, as a rule monthly. Chemical-analytical works were carried out in the accredited Department for Quality Control of Natural and Waste Waters of the Federal State Institution "VerkhneObregionvodkhoz" of the Federal Agency of Water Resources of the Russian Federation according to standard methods for analyzing of natural waters[1]. In total, 527 water samples were analyzed. The values of COD (chemical oxygen consumption), the concentration of bicarbonate ions, chloride ions and calcium ions were determined by the titrimetric method. The dissolved oxygen was measured by the iodometric method (Winkler's method). The content of various forms of mineral nitrogen, phosphate ions and phenols was determined by the photometric method. The content of sulfate ions was measured by the turbidimetric method. Oil products were determined by the IR spectrometric method. The metals content was measured by photometric and atomic absorption spectrometry methods.

The following hydrological and meteorological parameters were considered: water inflow into the reservoir and discharges to the downstream, the level and volume of the reservoir itself, water temperature, atmospheric precipitation, air temperature, the intensity of external water exchange. Data on the characteristics of the hydrological regime of the Novosibirsk Reservoir (the daily values of the average for the reservoir water level, inflow to the hydroelectric station and discharge to the downstream were used from literary and reference materials[2], [3]. The coefficients of external water exchange are calculated according to the formula of V.N. Stefan as the ratio of half-sum of the volume of the inflow and discharge to the reservoir volume determined according to actual data on the water level for the periods of time under consideration (Kitaev, 2009; Matarzin, 2003).

Meteorological information (air temperature, atmospheric precipitation) was obtained from the site Meteomanz.com[4]. For the upper and middle parts of the reservoir data on the Kamen-on-Ob weather station were used, for the lower part of the reservoir — on the weather station of Ogurtsovo.

Statistical manipulation of the data was carried out in the PAST program package. To analyze the influence of a complex of environmental factors that a priori are dependent on one another, a Canonical Correspondence Analysis (CCA) was used (Ter Braak, 1986).

Results and discussion

Previously, we determined strong statistically reliable connections (according to the Spirman Correlation Coefficient) between the intensity of water exchange and a number of chemical substances for the high-water year. The differences in these connections for the years of different water content (for the low-water 2012 and the high-water 2013) were revealed. It was shown that in high-water years water quality is more affected by the hydrological characteristics, while in low-water years intra-reservoir's processes influence mainly (Dvurechenskaya and Kondakova, 2020; Savkin and Dvurechenskaya, 2017; Savkin et al., 2020).

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[1] Regulatory documents RD 52.24 included in the Federal list of measurement techniques approved for use when performing work in the field of monitoring environmental pollution. Web page. URL: https://center-souz.ru/water/70-2009-05-04-10-33-51 (accessed: 27.02.2024).

[2] State Water Cadastre. Annual data on surface water regime and resources, 1990–2009. Part. 2. Lakes and Reservoirs. Vol. 1. Issue 10. Annual publication. West-Siberian Department on Hydrometeorology and Environmental Monitoring, Novosibirsk, Russia.

[3] Information system on water resources and water management of Russian river basins. Web page. URL: http://gis.vodinfo.ru (accessed: 18.10.2022).

[4] Meteomanz.com. Web page.URL: http://www.meteomanz.com (accessed: 20.10.2023).

The waters of the spring floods play a decisive role in the formation of water masses of reservoirs (Bogoslovskiy, 1980). The main inflow of water in the Novosibirsk reservoir occurs in May–June, in some years – also in April and July (Fig. 2). The period from July to August is characterized by the greatest development of the biota that also affects the quality of the water in the reservoir (Dvurechenskaya and Yermolaeva, 2014; Savkin et al., 2014).

The within-year variability in the hydrological characteristics of the Novosibirsk reservoir (on the example of 2005 – the mean one in water content) is shown in Figs. 2–3. The beginning and the end of the period under consideration was marked by thick vertical lines.

During the investigation period, the water level in April–June intensively increases as a result of the reservoir filling with spring flood waters, in July–August the water level is supported at the marks close to the normal maximum operating level (Savkin et al., 2014). The average long-term date for the beginning of filling the reservoir is April 14. The date of obtaining the normal maximum operating level is June 17. In the years under consideration the beginning of the filling fell on April 7 – 18, and the end was for the period from June 9 to July 9.

The Novosibirsk reservoir is a reservoir with a large water exchange (Fortunatov, 1974; Savkin et al., 2014). The average-year intensity of external water exchange is 6.65 times/year. The most intensive change in the water mass in the reservoir occurs in spring, with a maximum in May (Fig. 3). In the years under study the water exchange coefficient was equal to 6.21–6.82.

The results of the study of the water chemical composition of the Novosibirsk reservoir connection with hydrological and meteorological factors are presented in Tables 1–4.

The Canonical Correlation Analysis demonstrated that for the Novosibirsk Reservoir the eigenvalues of the first four axes explain 87.48% of the variance in the relationship of the chemical parameters of the water quality and the environmental factors. Moreover, the majority of the variance is explained by the first and second axes (Table 2). Hence, further discussions will be given for these axes.

Analyzing the data of Table 3, we can conclude that axis 1 is determined by all considered hydrological and meteorological parameters, and axis 2 is determined essentially by the water level, volume of the reservoir, precipitation and water exchange coefficient.

Table 4 shows that the strongest relationship of the concentration of chemical substances (all forms of mineral nitrogen, sulfates, phosphates, phenols, iron ions) was found with axis 1. On the other hand, COD, nitrates, chlorides, phosphates, and phenols, ions of iron, copper and chromium demonstrated significant relationship with axis 2.

As can be seen from the ordination diagram (Fig. 4), the content of chlorides, ammonium compounds, nitrites, nitrates, phosphates, iron ions, manganese ions, magnesium ions positively correlate with water exchange coefficient, the inflow and discharge of water in the reservoir and negatively with the volume of the reservoir, the water level, the temperature of water and air, precipitation. pH values, concentration of dissolved oxygen, alkalinity (HCO_3^- ions) and oil products, on the contrary, are negatively associated with the water exchange coefficient, but positively correlate with the volume of the reservoir, water level, water and air temperature, and precipitation. No correlation was observed between hydrological and meteorological parameters and COD, BOD and phenol concentrations. These ingredients, apparently, are more dependent on the content of substances entering the reservoir with the waters of the Ob River.

Our analysis makes it possible to conclude the significant effect of hydrological and meteorological factors on a number of hydrochemical characteristics of Novosibirsk reservoir water quality. The researches of other authors also confirm the same conclusion (Delpla et al., 2009; Dvurechenskaya et al., 2010; Savkin et al., 2014, 2020; Skaland et al., 2022; Zhu et al., 2021).

The results obtained confirmed that the water temperature is one of the most important factors that influence the transformation of chemicals in the Novosibirsk Reservoir water. The water temperature affects the physical, chemical, biochemical and biological processes that occur in the reservoir, on which the oxygen regime and intensity of self-purification processes largely depend (Grechushnikova, 2014; Dvurechenskaya et al., 2010; Pantelić, 2015). In the Novosibirsk Reservoir, an increase of temperature, in particular, leads to an increase in primary products and, accordingly, to the active consumption of biogenic substances and a decrease in their concentrations in water.

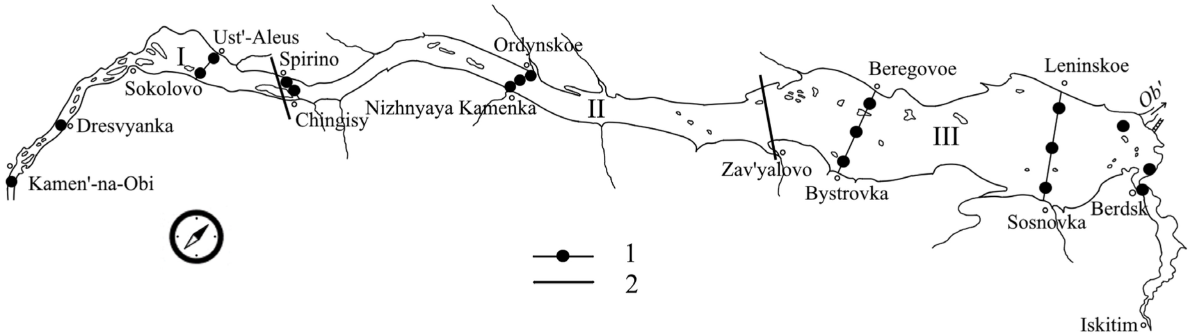

Fig. 1. Scheme of the Novosibirsk reservoir. 1 – sampling sites; 2 – boundary among reservoir parts; I – upper part, II – middle part, III –lower part.

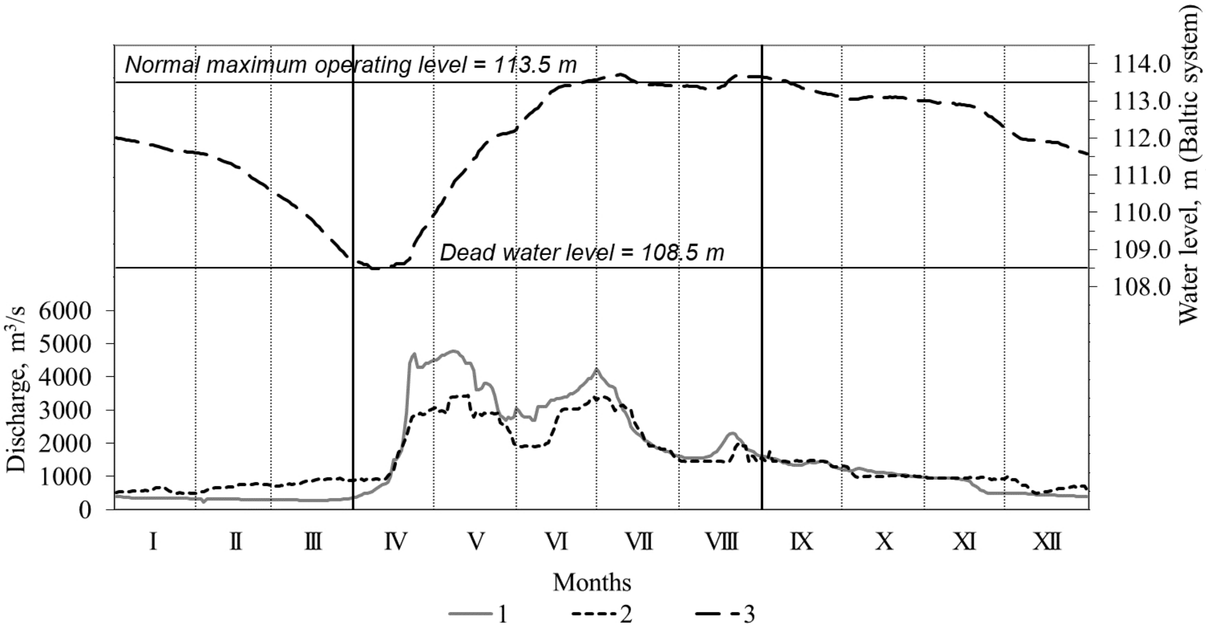

Fig. 2. Hydrological characteristics of the Novosibirsk reservoir in 2005. 1 – inflow into the reservoir, 2 – discharge to the downstream; 3 – water level.

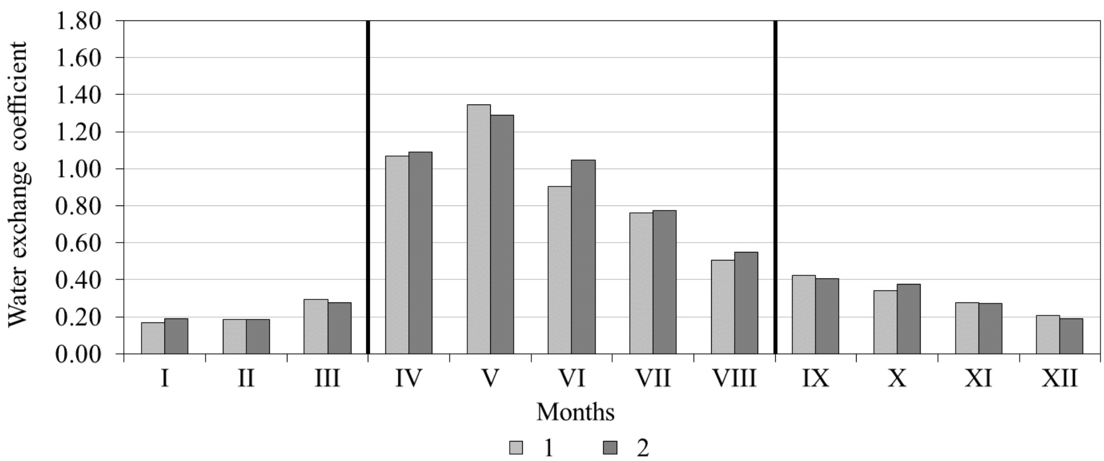

Fig. 3. Monthly external water exchange coefficients of the Novosibirsk reservoir. 1 – in 2005, 2 – average for 1960–2021.

Table 1. The content of chemicals in the waters of the Novosibirsk reservoir in the years of mean water content. BOD – biochemical oxygen demand over 5 days; COD – chemical oxygen demand.

Component	Mean value	Standard error
pH	8.131	0.020
HCO_3^-, mg-eq/l	2.511	0.041
O_2, mg/l	9.012	0.068
BOD, mgO_2/l	2.818	0.086
COD, mgO/l	12.835	0.506
NH_4^+, mgN/l	0.451	0.029
NO_2^-, mgN/l	0.011	0.002
NO_3^-, mgN/l	0.269	0.023
SO_4^{2-},mg/l	13.928	0.429
Cl^-, mg/l	5.859	0.198
PO_4^{3-},mg/l	0.073	0.015
Ca^{2+}, mg/l	30.222	0.492
Mg^{2+}, mg/l	9.384	0.379
oil products, mg/l	0.206	0.020
volatile phenols,mg/l	0.002	0.0002
Fe^{3+}, mg/l	0.339	0.019
Cu^{2+}, mg/l	0.005	0.0003
Cr^{3+}, mg/l	0.00047	0.00003
Ni^{2+}, mg/l	0.001	0.0001
Mn^{2+}, mg/l	0.031	0.004

Table 2. Percentage contribution of the explained dispersion of individual chemical parameters of water quality.

	Eigenvalue	% explained variance
Axis 1	0.0075	36.55
Axis 2	0.0057	27.41
Axis 3	0.0026	12.67
Axis 4	0.0022	10.85

Table 3. Contribution of hydrological and meteorological parameters to factor axes. Kw – water exchange coefficient, t-air – air temperature in the studied month, t-air-previous – air temperature in the month preceded the work, t-water – water temperature in the reservoir.

	Water inflow	Water discharge	Water level	Storage volume	Kw	t-air	t-air-previous	Precipi-tation	t-water
Axis 1	0.145	0.139	−0.312	−0.321	0.285	−0.398	−0.396	−0.145	−0.368
Axis 2	0.002	−0.011	−0.1812	−0.1809	0.106	0.013	−0.031	−0.187	−0.065

Table 4. Indices of the bonding forces of chemical substances with factor axes. The most significant bonds are highlighted in bold..

Component	Axis 1	Axis 2
pH	−0.086	−0.076
HCO_3^-	−0.002	−0.041
O_2	−0.031	−0.051
BOD	−0.015	0.055
COD	−0.103	0.122
NH_4^+	**0.142**	0.159
NO_2^-	**0.159**	0.080
NO_3^-	**0.258**	0.315
SO_4^{2-}	**0.162**	−0.031
Cl^-	**0.044**	**0.151**
PO_4^{3-}	**0.315**	**0.139**
Ca^{2+}	−0.033	−0.047
Mg^{2+}	0.058	0.028
oil products	−0.097	−0.007
volatile phenols	**0.176**	**−0.206**
Fe^{3+}	**0.322**	**0.156**
Cu^{2+}	−0.006	**−0.145**
Cr^{3+}	−0.164	**0.135**
Ni^{2+}	−0.119	−0.024
Mn^{2+}	0.067	0.046

The determining influence of hydrological factors on the hydrochemical regime of the reservoir is also shown. There is a "dilution effect" at high water exchange rates due to significant flow of water in the reservoir. The important role of the hydrological characteristics that essentially affect the productivity of the catchment basin and the quality of water in reservoirs is also indicated in a number of other works (Nazari-Sharabian and Taheriyun, 2022; Wang, et al., 2022, 2023).

Some studies discuss the role of atmospheric precipitation in the formation of hydrochemical regime of reservoirs (Han et al., 2018; Lecomte et al., 2022). With more precipitation, the concentration of a number of chemicals, primarily biogenes (phosphates and all forms of mineral nitrogen) decreases. The pH-values do not change appreciably. However, the concentrations of the studied chemicals depend more on temperature and hydrological parameters of the reservoir than on precipitation. In the case of the Novosibirsk Reservoir a low level of effect of precipitation on the water quality can be an indicator of the features of the catchment area.

Conclusions

The water quality of the Novosibirsk Reservoir is affected both by natural factors associated with flow fluctuations of the Ob River, meteorological parameters, as anthropogenic factors, due to the regulation of its water reserves (the regime of flushes in the downstream), the intake of pollutants with the water flow of the Ob River and from point and diffuse wastewater sources.

It was shown that pH values, the concentration of dissolved oxygen, alkalinity, the content of chlorides, ammonium compounds, nitrites, nitrates, phosphates, iron ions, manganese ions, magnesium

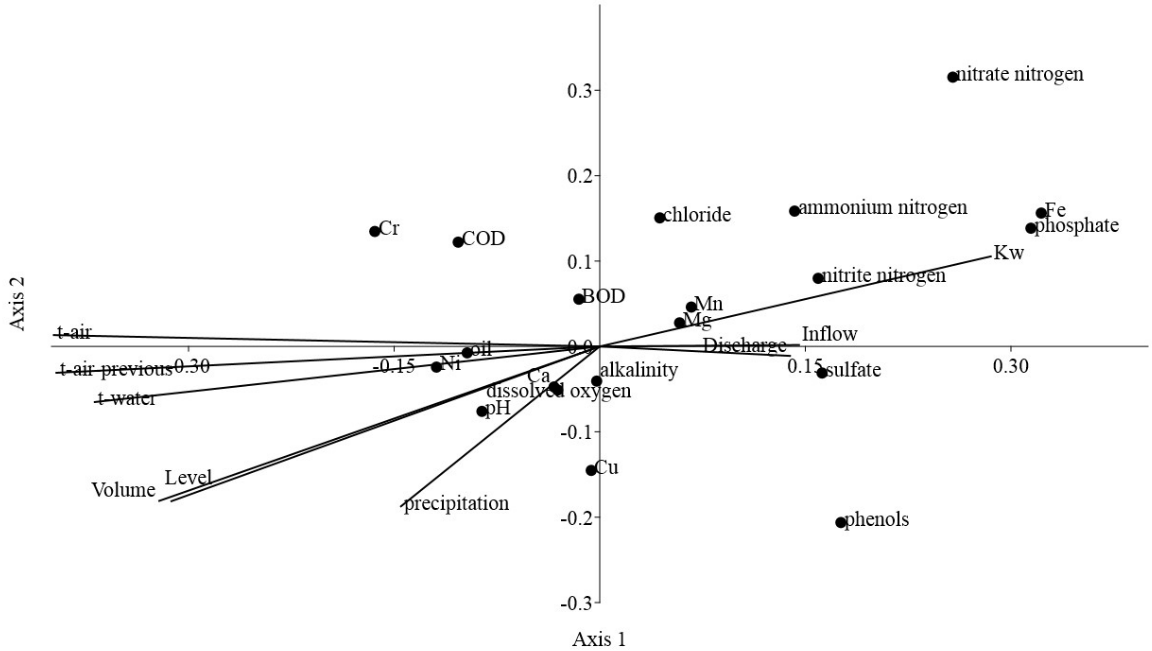

Fig. 4. Ordination diagram (CCA – Canonical Correspondence Analysis) of the dependence of chemical ingredients on environmental parameters; t-water – water temperature, t-air – air temperature, t-air previous – air temperature for previous month, Kw – water exchange factor, Volume – reservoir volume, Level – water level, BOD – biochemical oxygen demand over 5 days, COD – chemical oxygen demand, oil – petroleum products, precipitation – atmospheric rainfall.

ions, oil products are correlated with the intensity of water exchange, inflow and water discharge, with the volume of the reservoir, water temperature and atmospheric precipitation.

The Novosibirsk Reservoir is a water body with a small regulating prism and a large coefficient of water exchange. Apparently, the fact that for a number of chemical parameters, such as BOD – biochemical oxygen demand over 5 days; COD – chemical oxygen demand, phenols dependence on the considered hydrological and meteorological characteristics does not evaluated. Their content, apparently, is mainly determined by the influx of chemical substances brought by the Ob River.

The results of the work can be used to make the administrative decisions in the field of water use, taking into account the forecast of changes in the water and ecological status of the Novosibirsk Reservoir.

References

Avakian, A.B., Saltankin, V.P., Sharapov, V.A., 1987. Vodokhranilishcha [Reservoirs]. Mysl, Moscow, USSR, 323 p. (In Russian).

Alekin, O.A., 1970. Osnovy gidrokhimii [Fundamentals of hydrochemistry]. Gidrometeoizdat, Leningrad, USSR, 442 p. (In Russian).

Atavin, A.A., Belonenko, G.V., Vinokurov, Yu.I., Voronkov, G.V., Dalkov, M.P. et al., 1997. Vodokhozyaystvennyy kompleks v FTsP “Sibir” [Water management complex in the Federal Target Program “Siberia”]. *Obskoy vestnik [Ob Bulletin]* **2–3**, 99–103. (In Russian).

Bogoslovskiy, B.B., 1980. Volny, techeniya i vodnyye massy vodoyemov [Waves, currents and water masses of reservoirs]. Leningrad Hydrometeorological Institute, Leningrad, USSR, 57 p. (In Russian).

Calijuri, M.L., Castro, J.S., Costa, L.S., Assemany, P.P., Alves, J.E. et al., 2015. Impact of land use/land cover changes on water quality and hydrological behavior of an agricultural subwatershed. *Environmental Earth Sciences* **74,** 5373–5382. https://doi.org/10.1007/s12665-015-4550-0

Chaykina, M.V., 1975. Gidrokhimicheskiy rezhim Novosibirskogo vodokhranilishcha [Hydrochemical regime of the Novosibirsk reservoir]. Nauka, Novosibirsk, USSR, 130 p. (In Russian).

da Rocha, M.P., Dourado, P.L.R., de Souza Rodrigues, M., Raposo, J.L., Grisolia, A.B., de Oliveira, K.M.P., 2015. The influence of industrial and agricultural waste on water quality in the Água Boa stream (Dourados, Mato Grosso do Sul, Brazil). *Environmental Monitoring and Assessment* **187,** 442. https://doi.org/10.1007/s10661-015-4475-9

Delpla, I., Jung, A.-V., Baures, E., Clement, M., Thomas, O., 2009. Impacts of climate change on surface water quality in relation to drinking water production. *Environment International* **35** (8), 1225–1233. https://doi.org/10.1016/j.envint.2009.07.001

Dvurechenskaya, S.Ya., 2012. Analysis of consequences of contribution from major sources of chemical matter in water of Novosibirsk reservoir. *Contemporary Problems of Ecology* **5** (4), 347–351.

Dvurechenskaya, S.Ya., Yermolaeva, N.I., 2014. Interrelations between chemical composition of water and characteristics of zooplankton in the Novosibirsk reservoir. *Contemporary Problems of Ecology* **7** (4), 464–472.

Dvurechenskaya, S.Ya., Kondakova,O.V., 2020. The effect of the external water cycle on certain water quality parameters of the Novosibirsk Reservoir in different water-content years. *Limnology and Freshwater Biology* **4**, 916–917. https://doi.org/10.31951/2658-3518-2020-A-4-916

Dvurechenskaya, S.Ya., Yermolaeva, N.I., Savkin, V.M., 2010. Kompleksnyi monitoring i ekologicheskiye problemy Novosibirskogo vodokhranilishcha [Complex monitoring and environmental problems of the Novosibirsk reservoir]. *Materialy Vserossiyskoy nauchno-prakticheskoy konferentsii "Nauchnyye osnovy ekologicheskogo monitoringa vodokhranilishch" [Materials of the All-Russian scientific and practical conference "Scientific foundations of ecological monitoring of reservoirs"].* Khabarovsk, Russia, 53–56. (In Russian).

Fortunatov, M.A., 1974. O protochnosti i vodoobmene vodokhranilishch [About the flow and water exchange of reservoirs]. *Trudy Instituta biologii vnutrennikh vod [Proceedings of the Institute for Biology of Inland Waters Academy of Sciences USSR]* **26**, 111–120. (In Russian).

Grechushnikova M.G. 2014, Prostranstvennye i sinopticheskie variacii fiziko-khimicheskikh kharakteristik Mozhajskogo vodokhranilishha [Spatial and synoptic variations of physical-chemical characteristics of Mojai reservoir]. Vestnik TGU [Tomsk State University Bulletin] **19** (5), 1671–1674 (In Russian).

Han, T., Li, Yu., Qin, J., Yang, Q., He, X.,2018**.** Hydrochemical changes and influencing factors in the Dongkemadi region, Tanggula Range, China.*Water* ***10(***12), 1856. https://doi.org/10.3390/w10121856

Kitayev, A.B., 2009. Pokazateli vneshnego vodoobmena iskusstvennykh vodoyemov [Features of external water exchange of artificial reservoirs]. *Geograficheskiy vestnik [Geographical Bulletin]* **2**, 27–32. (In Russian).

Lanbina, T.V., Karpeyeva, T.V., 1985. Rezhim biogennykh i organicheskikh veshchestv Novosibirskogo vodokhranilishcha [Regime of biogenic and organic substances of the Novosibirsk reservoir]. In: Podlipskiy, Yu.I. (ed.), *Kompleksnyye issledovaniya Novosibirskogo vodokhranilishcha (Trudy ZapSibregNIGMI. Vyp. 70) [Comprehensive studies of the Novosibirsk reservoir (Proceedings of West Siberian Research-Scientific Institute of the Russian Committee of Hydrometeorology. Is. 70)].* Moscow Branch of Gigrometeoizdat, Moscow, USSR, 24–42. (In Russian).

Lecomte, K.L., Pasquini, A.I., Manjarrez-Rangel, C.S., Alquiza, P., Segoviano-Garfias, J., Zanor, G., 2022. Surface hydrochemical dynamic in an artificial lake with anthropic impact: La Purísima reservoir, Central Mexico. *Environmental Monitoring and Assessment* **194**, 128. https://doi.org/10.1007/s10661-022-09773-4

Li, S., Xu, Y.J., Ni, M., 2021. Changes in sediment, nutrients and major ions in the world largest reservoir: Effects of damming and reservoir operation. *Journal of Cleaner Production* **318**(4), 128601.https://doi.org/10.1016/j.jclepro.2021.128601

Matarzin, Yu.M., 2003. Gidrologiya vodokhranilishch: Uchebnik dlya vuzov [Hydrology of reservoirs: Textbook for universities]. Publishing House of the Perm State University, Perm, Russia, 295 p. (In Russian).

Nazari-Sharabian, M., Taheriyoun, M., 2022.Climate change impact on water quality in the integrated Mahabad Dam watershed-reservoir system. *Journal of Hydro-Environment Research*. **40**, 28–37. https://doi.org/10.1016/j.jher.2021.12.001

Nikanorov, A.M., Posokhov, E.V., 1985. Gidrokhimiya [Hydrochemistry]. Gidrometeoizdat, Leningrad, USSR, 232 p. (In Russian).

Pantelić, M., Dolinaj, D., Leščešen, I., Savić, S., Milošević, D., 2015. Water quality of the Pannonian basin rivers the Danube, the Sava and the Tisa (Serbia) and its correlation with air temperature. *Thermal Science* **19** (2), 477–485. https://doi.org/10.2298/TSCI150325114P

Podlipskiy, Yu.I., 1985. K voprosu organizatsii i nekotoryye itogi kompleksnykh issledovaniy Novosibirskogo vodokhranilishcha [On the issue of organization and some results of complex studies of the Novosibirsk reservoir]. In: Podlipskiy, Yu.I. (ed.), *Kompleksnyye issledovaniya Novosibirskogo vodokhranilishcha (Trudy ZapSibregNIGMI. Vyp. 70) [Comprehensive studies of the Novosibirsk reservoir (Proceedings of West Siberian Research-Scientific Institute of the Russian Committee of Hydrometeorology. Is. 70)].* Moscow Branch of Gigrometeoizdat, Moscow, USSR, 3–16. (In Russian).

Rozenberg, G.S., Evlanov, I.A., Seleznev, V.A., Mineyev, A.K., Selezneva, A.V., Shitikov, V.K., 2011. Opyt ekologicheskogo normirovaniya antropogennogo vozdeystviya na kachestvo vody (na primere vodokhranilishch Sredney i Nizhney Volgi) [Experience of ecological regulation of anthropogenic impact on water quality (on the example of reservoirs of the Middle and Lower Volga)]. *Materialy Obyedinennogo Plenuma Nauchnogo soveta OBN RAN po gidrobiologii i ikhtiologii Gidrobiologicheskogo obshchestva pri RAN i Mezhvedomstvennoy ikhtiologicheskoy komissii. Voprosy ekologicheskogo normirovaniya i razrabotka sistemy otsenki sostoyaniya vodoyemov [Materials of the Joint Plenum of the Scientific Council of the RAS on Hydrobiology and Ichthyology of the Hydrobiological Society at the RAS and the Interdepartmental Ichthyological Commission. Issues of environmental regulation and development of a system for assessing the state of reservoirs].* KMK Scientific Press Ltd, Moscow, Russia, 196 p. (In Russian).

Savkin, V.M., 2000. Ekologo-geograficheskiye izmeneniya v basseynakh rek Zapadnoy Sibiri [Ecological and geographical changes in the river basins of Western Siberia]. Nauka, Novosibirsk, Russia, 152 p. (In Russian).

Savkin, V.M., Dvurechenskaya, S.Ya., 2014. Resources-related and water-environmental problems of the integrated use of the Novosibirsk reservoir. *Water Resources* **41** (4), 446–453. https://doi.org/10.7868/S0321059614030158

Savkin, V.M., Dvurechenskaya, S.Ya., 2017. Izmeneniye kachestva vody Verkhney Obi (na primere Novosibirskogo vodokhranilishcha) v razlichnyye gidrologicheskiye periody [Changes in the water quality of the Upper Ob (on the example of the Novosibirsk reservoir) in various hydrological periods].

Problemy ekologicheskogo monitoringa i modelirovaniya ekosistem [Problems of Environmental Monitoring and Ecosystem Modeling] **28** (3), 72–83. (In Russian). https://doi.org/10.21513/0207-2564-2017-3-72-83

Savkin, V.M., Dvurechenskaya, S.Ya., 2018. Vliyaniye mnogoletnego kompleksnogo ispolzovaniya vodnykh resursov na ekosistemu Novosibirskogo vodokhranilishcha [The impact of long-term integrated use of water resources on the ecosystem of the Novosibirsk reservoir]. *Voda i ekologiya: problemy i resheniya [Water and Ecology: Problems and Decisions]* **1** (73), 71–82. (In Russian). https://doi.org/10.23968/2305-3488.2018.23.1.71-82

Savkin, V.M., Dvurechenskaya, S.Ya., Yermolaeva, N.I., Kipriyanova, L.M., Kirillov, V.V. et al., 2014. Mnogoletnyaya dinamika vodno-ekologicheskogo rezhima Novosibirskogo vodokhranilishcha [Long-term dynamics of the water-ecological regime of the Novosibirsk reservoir]. Siberian Branch RAS, Novosibirsk, Russia, 393 p. (In Russian).

Savkin, V.M., Dvurechenskaya, S.Ya., Kondakova, O.V., 2018. Kompleksnoye ispolzovaniye vodnykh resursov Verkhney Obi v usloviyakh razlichnoy vodnosti [Integrated use of water resources of the Upper Ob in conditions of different water content]. *Materialy Vserossiyskoy nauchno-prakticheskoy konferentsii "Vodnyye resursy Rossii: sovremennoye sostoyaniye i upravleniye". T. 1 [Materials of the All-Russian scientific and practical conference "Water resources of Russia: current state and management". Vol. 1].* Lik, Novocherkssk, Russia, 169–176. (In Russian).

Savkin, V.M., Dvurechenskaya, S.Ya., Kondakova, O.V., 2020. Vliyaniye Novosibirskogo vodokhranilishcha na formirovaniye gidrologo-gidrokhimicheskogo rezhima Verkhney Obi na zaregulirovannom uchastke [The influence of the Novosibirsk reservoir on the formation of the hydro-hydrochemical regime of the Upper Ob in the regulated area]. *Voda i ekologiya: problemy i resheniya [Water and Ecology: Problems and Decisions]* **1**, 51–62. (In Russian). https://doi.org/10.23968/2305-3488.2020.25.1.51-62

Salnikov, N.E., Sappo, L.M., 2005. Nekotoryye osobennosti formirovaniya gidrokhimicheskogo rezhima i kachestvo vody Ivankovskogo vodokhranilishcha v 1996–2000 gg. [Some features of the formation of the hydrochemical regime and the water quality of the Ivankovo reservoir in 1996–2000]. *Gidrobiologicheskiy zhurnal [Hydrobiological Journal]* **41** (2), 73–84. (In Russian).

Setegn, S.G., 2015. Water resources management for sustainable environmental public health. In: Setegn, S.G., Donoso, M.C. (eds.), *Sustainability of integrated water resources management: water governance, climate and ecohydrology*. Springer International Publishing, Switzerland, 275–287. https://doi.org/10.1007/978-3-319-12194-9_15

Skaland, R.G., Herrador, B.G., Hisdal, H., Hygen, H.O., Hyllestad, S. et al., 2022. Impacts of climate change on drinking water quality in Norway. *Journal of Water and Health* **20** (3), 539–550. https://doi.org/10.2166/wh.2022.264

Ter Braak, C.J., 1986. Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. *Ecology* **67**, 1167–1179.

Timchenko, V.M., 2006. Ekologicheskaya gidrologiya dneprovskikh vodokhranilishch [Ecological hydrology of the Dnieper reservoirs]. *Gidrobiologicheskiy zhurnal [Hydrobiological Journal]* **42** (3), 81–96. (In Russian).

Vasiliev, O.F., Burakov, D.A., Vostryakova, N.V., Savkin, V.M., 1990. Perspektivy regulirovaniya stoka v Ob-Irtyshskom basseyne v svyazi s meliorativnym osvoyeniyem territorii. Gidrologicheskoye obosnovaniye vodokhozyaystvennykh meropriyatiy [Prospects of flow regulation in the Ob-Irtysh basin in connection with the reclamation development of the territory. Hydrological justification of water management measures]. *Trudy V Vsesoyuznogo gidrologicheskogo syezda [Proceedings of the V All-Union Hydrological Congress]* **4**. 159–164. (In Russian).

Vasiliev, O.F., Savkin, V.M., Dvurechenskaya, S.Ya., Popov, P.A., 1997. Vodokhozyaystvennye i ekologicheskiye problemy Novosibirskogo vodokhranilishcha [Water management and environmental problems of the Novosibirsk reservoir]. *Vodnyye resursy [Water Resources]* **24** (5), 581–589. (In Russian).

Wang, J., Yin, W., Wang, L., Li, N., Xu, J.F. et al., 2022. Unraveling the effects of hydrological connectivity and landscape characteristics on reservoir water quality. *Journal of Hydrology* **613**(3), 128410. https://doi.org/10.1016/j.jhydrol.2022.128410

Wang, K., Pang, Yu., Yi, Yu., Yang, Sh., Wang, Yu.et al., 2023. Response of dissolved organic matter chemistry to flood control of a large river reservoir during an extreme storm event.*Water Research* **230**, 119565. https://doi.org/10.1016/j.watres.2023.119565

Zhu, L., Panthi, Ch., Jiang, S., Sapkota, A., 2021. Impact of high precipitation and temperature events on the distribution of emerging contaminants in surface water in the Mid-Atlantic, United States. *Science of The Total Environment* **755** (2), 142552. https://doi.org/10.1016/j.scitotenv.2020.142552

Znamensky, V.A., 1981. Gidrologicheskie processy i ikh rol' v formirovanii kachestva vody [Hydrological processes and their role in the formation of water quality]. Gidrometeoizdat, Leningrad, USSR, 248 p. (In Russian).

Список литературы

Авакян, А.Б., Салтанкин, В.П., Шарапов, В.А., 1987. Водохранилища. Мысль, Москва, СССР, 323 с.

Алекин, О.А., 1970. Основы гидрохимии. Гидрометеоиздат, Ленинград, СССР, 442 с.

Атавин, А.А., Белоненко, Г.В., Винокуров, Ю.И., Воронков, Г.В., Дальков, М.П. и др., 1997. Водохозяйственный комплекс в ФЦП «Сибирь». *Обской вестник* **2–3**, 99–103.

Богословский, Б.Б., 1980. Волны, течения и водные массы водоемов. Ленинградский Гидрометеорологический институт, Ленинград, СССР, 57 с.

Васильев, О.Ф., Бураков, Д.А., Вострякова, Н.В., Савкин, В.М., 1990. Перспективы регулирования стока в Обь-Иртышском бассейне в связи с мелиоративным освоением территории. Гидрологическое обоснование водохозяйственных мероприятий. *Труды V Всесоюзного гидрологического съезда* **4**, 159–164.

Васильев, О.Ф., Савкин, В.М., Двуреченская, С.Я., Попов, П.А., 1997. Водохозяйственные и экологические проблемы Новосибирского водохранилища. *Водные ресурсы* **24 (**5), 581–589.

Гречушникова, М.Г. 2014. Пространственные и синоптические вариации физико-химических характеристик Можайского водохранилища. *Вестник ТГУ* **19** (5), 1671–1674.

Двуреченская, С.Я., 2012. Анализ роли различных источников поступления химических веществ в воды Новосибирского водохранилища. *Сибирский экологический журнал* **19** (4), 473–478.

Двуреченская, С.Я., Ермолаева, Н.И., 2014. Выявление взаимосвязей химического состава воды Новосибирского водохранилища и характеристик зоопланктона. *Сибирский экологический журнал* **21** (4), 615–625.

Двуреченская, С.Я., Ермолаева, Н.И., Савкин, В.М., 2010. Комплексный мониторинг и экологические проблемы Новосибирского водохранилища. *Материалы Всероссийской научно-практической конференции «Научные основы экологического мониторинга водохранилищ»*. Хабаровск, Россия, 53–56.

Знаменский, В.А., 1981. Гидрологические процессы и их роль в формировании качества воды. Гидрометеоиздат, Ленинград, СССР, 248 с.

Китаев, А.Б., 2009. Показатели внешнего водообмена искусственных водоемов. *Географический вестник* **2**, 27–32.

Ланбина, Т.В., Карпеева, Т.В., 1985. Режим биогенных и органических веществ Новосибирского водохранилища. В: Подлипский, Ю.И. (ред.),*Комплексные исследования Новосибирского водохранилища* (*Труды ЗапСибНИИГоскомгидромета*. *Вып. 70)*. Московское отделение Гидрометеоиздата, Москва, СССР, 24–42.

Матарзин, Ю.М., 2003. Гидрология водохранилищ: Учебник для вузов. Издательство ПГУ, Пермь, Россия, 295 с.

Никаноров, А.М., Посохов, Е.В., 1985. Гидрохимия. Гидрометеоиздат, Ленинград, СССР, 232 с.

Подлипский, Ю.И., 1985. К вопросу организации и некоторые итоги комплексных исследований Новосибирского водохранилища. В: Подлипский, Ю.И. (ред.),*Комплексные исследования Новосибирского водохранилища* (*Труды ЗапСибНИИГоскомгидромета*. *Вып. 70)*. Московское отделение Гидрометеоиздата, Москва, СССР, 3–16.

Розенберг, Г.С., Евланов, И.А., Селезнёв, В.А., Минеев, А.К., Селезнёва, А.В., Шитиков, В.К., 2011. Опыт экологического нормирования антропогенного воздействия на качество воды (на примере водохранилищ Средней и Нижней Волги). *Материалы Объединенного Пленума Научного совета ОБН РАН по гидробиологии и ихтиологии Гидробиологического общества при РАН и Межведомственной ихтиологической комиссии. Вопросы экологического нормирования и разработка системы оценки состояния водоемов.* Товарищество научных изданий КМК, Москва, Россия, 196 с.

Савкин, В.М., 2000. Эколого-географические изменения в бассейнах рек Западной Сибири. Наука, Новосибирск, Россия, 152 с.

Савкин, В.М., Двуреченская, С.Я., 2014. Ресурсные и водно-экологические проблемы комплексного использования Новосибирского водохранилища. *Водные ресурсы* **41** (4), 456–465. https://doi.org/10.7868/S0321059614030158

Савкин, В.М., Двуреченская, С.Я., 2017. Изменение качества воды Верхней Оби (на примере Новосибирского водохранилища) в различные гидрологические периоды. *Проблемы экологического мониторинга и моделирования экосистем* **28** (3), 72–83. https://doi.org/10.21513/0207-2564-2017-3-72-83

Савкин, В.М., Двуреченская, С.Я., 2018. Влияние многолетнего комплексного использования водных ресурсов на экосистему Новосибирского водохранилища. *Вода и экология: проблемы и решения* **1**(73), 71–82. https://doi.org/10.23968/2305-3488.2018.23.1.71-82

Савкин, В.М., Двуреченская, С.Я., Ермолаева, Н.И., Киприянова, Л.М., Кириллов, В.В. и др., 2014. Многолетняя динамика водно-экологического режима Новосибирского водохранилища. СО РАН, Новосибирск, Россия, 393 с.

Савкин, В.М., Двуреченская, С.Я., Кондакова, О.В. 2018. Комплексное использование водных ресурсов Верхней Оби в условиях различной водности. *Материалы Всероссийской научно-практической конференции «Водные ресурсы России: современное состояние и управление». Т. 1.* Лик, Новочеркасск, Россия, 169–176.

Савкин, В.М., Двуреченская, С.Я., Кондакова, О.В., 2020. Влияние Новосибирского водохранилища на формирование гидролого-гидрохимического режима Верхней Оби на зарегулированном участке. *Вода и экология: проблемы и решения* **1**, 51–62. https://doi.org/10.23968/2305-3488.2020.25.1.51-62

Сальников, Н.Е., Саппо, Л.М., 2005. Некоторые особенности формирования гидрохимического режима и качество воды Иваньковского водохранилища в 1996–2000 гг. *Гидробиологический журнал* **41** (2), 73–84.

Тимченко, В.М., 2006. Экологическая гидрология днепровских водохранилищ. *Гидробиологический журнал* **42** (3), 81–96.

Фортунатов, М.А., 1974. О проточности и водообмене водохранилищ. *Труды Института биологии внутренних вод АН СССР* **26**, 111–120.

Чайкина, М.В., 1975. Гидрохимический режим Новосибирского водохранилища. Наука, Новосибирск, СССР, 130 с.

Calijuri, M.L., Castro, J.S., Costa, L.S., Assemany, P.P., Alves, J.E. et al., 2015. Impact of land use/land cover changes on water quality and hydrological behavior of an agricultural subwatershed. *Environmental Earth Sciences* **74,** 5373–5382. https://doi.org/10.1007/s12665-015-4550-0

da Rocha, M.P., Dourado, P.L.R., de Souza Rodrigues, M., Raposo, J.L., Grisolia, A.B., de Oliveira, K.M.P., 2015. The influence of industrial and agricultural waste on water quality in the Água Boa stream (Dourados, Mato Grosso do Sul, Brazil). *Environmental Monitoring and Assessment* **187,** 442. https://doi.org/10.1007/s10661-015-4475-9

Delpla, I., Jung, A.-V., Baures, E., Clement, M., Thomas, O., 2009. Impacts of climate change on surface water quality in relation to drinking water production. *Environment International* **35** (8), 1225–1233. https://doi.org/10.1016/j.envint.2009.07.001

Dvurechenskaya, S.Ya., Kondakova,O.V., 2020. The effect of the external water cycle on certain water quality parameters of the Novosibirsk Reservoir in different water-content years. *Limnology and Freshwater Biology* **4**, 916–917. https://doi.org/10.31951/2658-3518-2020-A-4-916

Han, T., Li, Yu., Qin, J., Yang, Q., He, X.,2018**.** Hydrochemical changes and influencing factors in the Dongkemadi region, Tanggula Range, China.*Water **10**(*12), 1856. https://doi.org/10.3390/w10121856

Lecomte, K.L., Pasquini, A.I., Manjarrez-Rangel, C.S., Alquiza, P., Segoviano-Garfias, J., Zanor, G., 2022. Surface hydrochemical dynamic in an artificial lake with anthropic impact: La Purísima reservoir, Central Mexico. *Environmental Monitoring and Assessment* **194**, 128. https://doi.org/10.1007/s10661-022-09773-4

Li, S., Xu, Y.J., Ni, M., 2021. Changes in sediment, nutrients and major ions in the world largest reservoir: Effects of damming and reservoir operation. *Journal of Cleaner Production* **318**(4), 128601.https://doi.org/10.1016/j.jclepro.2021.128601

Nazari-Sharabian, M., Taheriyoun, M., 2022.Climate change impact on water quality in the integrated Mahabad Dam watershed-reservoir system. *Journal of Hydro-Environment Research*. **40**, 28–37. https://doi.org/10.1016/j.jher.2021.12.001

Pantelić, M., Dolinaj, D., Leščešen, I., Savić, S., Milošević, D., 2015. Water quality of the Pannonian basin rivers the Danube, the Sava and the Tisa (Serbia) and its correlation with air temperature. *Thermal Science* **19** (2), 477–485. https://doi.org/10.2298/TSCI150325114P

Setegn, S.G., 2015. Water resources management for sustainable environmental public health. In: Setegn, S.G., Donoso, M.C. (eds.), *Sustainability of integrated water resources management: water governance, climate and ecohydrology*. Springer International Publishing, Switzerland, 275–287. https://doi.org/10.1007/978-3-319-12194-9_15

Skaland, R.G., Herrador, B.G., Hisdal, H., Hygen, H.O., Hyllestad, S. et al., 2022. Impacts of climate change on drinking water quality in Norway. *Journal of Water and Health* **20** (3), 539–550. https://doi.org/10.2166/wh.2022.264

Ter Braak, C.J., 1986. Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. *Ecology* **67**, 1167–1179.

Wang, J., Yin, W., Wang, L., Li, N., Xu, J.F. et al., 2022. Unraveling the effects of hydrological connectivity and landscape characteristics on reservoir water quality. *Journal of Hydrology* **613**(3), 128410. https://doi.org/10.1016/j.jhydrol.2022.128410

Wang, K., Pang, Yu., Yi, Yu., Yang, Sh., Wang, Yu.et al., 2023. Response of dissolved organic matter chemistry to flood control of a large river reservoir during an extreme storm event.*Water Research* **230**, 119565. https://doi.org/10.1016/j.watres.2023.119565

Zhu, L., Panthi, Ch., Jiang, S., Sapkota, A., 2021. Impact of high precipitation and temperature events on the distribution of emerging contaminants in surface water in the Mid-Atlantic, United States. *Science of The Total Environment* **755** (2), 142552. https://doi.org/10.1016/j.scitotenv.2020.142552