Estimation of the Variability of Average Annual Values of Nutrients Concentrations in the Water of the Kuibyshev Reservoir

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Abstract. The results of the analysis of water pollution in the Kuibyshev reservoir with nutrients for the period 2009-2015 yrs are given. The assessment of the dynamics of average annual concentrations of biogenic substances and comparison with fisheries standards was carried out. The trends of average annual concentrations of biogenic substances in the water of the Kuibyshev reservoir are obtained, describing the general trend of the dynamics of biogenic substances for the studied period of time. The analysis of the changes in the chemical composition of the nutrient elements of the waters of the Kuibyshev reservoir in retrospective years from 1957-2015 yrs was carried out. In the modern period of 2009-2015 yrs marked a significant increase compared with 1952-1954 yrs the concentrations of the main biogenic substances - phosphate ions - 6,3 times, nitrite ions - 35,0 times, nitrate ions - 15,6 times, and ammonium ions 23,0 times.

1. Introduction
The Kuibyshev reservoir is among the top ten largest in the world by the water surface of the world’s water reservoirs (6,5 thousand km²). This is the largest reservoir of the Volga-Kama cascade, which controls 97% of the water resources of the Volga [1]. Functionally, the Kuibyshev reservoir is a reservoir of seasonal regulation and multi-purpose, which is used in the interests of a number of sectors of the economy: industry and energy, drinking and household water supply, health care, agriculture, fish, forestry and hunting, mining, transport, recreation, construction, fire safety, etc. [2].

The water quality of the Kuibyshev reservoir is formed under the influence of transit transport of pollutants from overlying subjects of the Russian Federation, as well as due to discharges of insufficiently treated wastewater from industrial and municipal enterprises and surface runoff from an urbanized area adjacent to the reservoir water area [3]. The main contribution to water pollution in the Kuibyshev reservoir is the transit transport of pollutants from the territories of the overlying constituent entities of the Russian Federation. At the same time, the main flow of pollutants is carried out along the channel part of the reservoir. Due to the significant fluctuations in the water level caused by the alignment of the reservoir mirror during the flood period, changes in the operating mode of the
Kuibyshev hydroelectric station and wind surge part of the pollutants can flow from the channel part of the reservoir to shallow water. In addition, a significant contribution to the pollution of water bodies is made by the geological environment and aerotechnogenic pollution [4, 5]. And this is not a complete list of the most significant factors that cause pollution of the water resources of the Kuibyshev reservoir and its tributaries.

At present, anthropogenic eutrophication is the most significant problem of the Kuibyshev reservoir. First of all, this interest is due to the close connection of the effects of nutrient pollution with the formation and transformation of the water quality of the reservoir as a source of water supply [6, 7]. In addition, excessive introduction of nutrient substances under conditions of slow water exchange causes massive development of blue-green algae and blooming of water, which significantly impairs its quality, reduces the recreational and fisheries potential of the reservoir.

This article is a continuation of a series of papers [8 – 11] devoted to the assessment of water quality, the rationing of chemical stress and the assessment of pollution by nutrients of the Kuibyshev reservoir and its tributaries.

2. Materials and methods

As source materials, systematic observations of the Sredvolgavodkhoz Federal State Budgetary Institution of water pollution of the Kuibyshev reservoir at strained water use areas, as well as at the boundaries between constituent entities of the Russian Federation, were used as source materials.

Water sampling was carried out during the main phases of the water regime: winter low water, high water (on the rise, peak and recession), summer low flow, in the fall before freezing, as well as during the passage of rain flood. Monitoring of water pollution in the Kuibyshev reservoir was carried out at 12 hydrochemical monitoring stations.

Calculation of the excess concentrations of nutrients substances are given in multiplicities of MPC of fishery value. According to the results of hydrochemical analysis, the average annual and average values for 2009–2015 are calculated. Values of concentrations of biogenic substances in fractions of MPC in the whole of the Kuibyshev reservoir.

In order to obtain comparable information, the processing of observations of water pollution in the Kuibyshev reservoir was carried out using physical and statistical analysis methods given in [12, 13].

3. Results and discussion

Ammonium ions Dynamics and trend of average annual concentrations of ammonium ions in fractions of MPC for the period 2009-2015 yrs in the water of the Kuibyshev reservoir are shown in Fig. 1

![Figure 1](image_url)
The average long-term concentration of ammonium ions for the period from 2009 to 2015 yrs was 0.86 MPC. The maximum average multi-year concentration is 1.5 MPC was observed in 2010, and the minimum 0.55 MPC in 2011. On average, the concentration of ammonium ions decreased by 0.09 MPC from year to year.

The excess of fisheries standards was registered in 2009 and 2010 1.37 and 1.5 times, respectively. Analysis of fig. 2 shows that for the period 2009-2015, in the water of the Kuibyshev reservoir, there was a moderate trend of a decrease in the average annual concentrations of ammonium ions.

*Nitrite - and nitrate ions* Dynamics and trend of average annual concentrations of nitrate ions in fractions of MPC for the period 2009-2015 yrs in the water of the Kuibyshev reservoir are shown in Fig. 2.

![Figure 2](attachment:image.png)

**Figure 2.** Long-term dynamics and trend of average annual concentrations of nitrate ions for the period 2009-2015 yrs in the water of the Kuibyshev reservoir, in multiplicities of MPC.

On average, the concentration of nitrate ions grew by 0.0001 MPC from year to year. Excess of fishery standards by average long-term concentrations of nitrate ions in the water of the Kuibyshev reservoir for the period 2009-2015 yrs not identified. Analysis of fig. 3 shows that in the period 2009-2015 yrs in the water of the Kuibyshev reservoir there was a weak tendency of growth of average annual concentrations of nitrate ions.

Long-term dynamics and trend of average annual concentrations of nitrite ions in the water of the Kuibyshev reservoir over the period 2009-2015 yrs is shown in fig. 3. On average, the concentration of nitrite ions increased by 0.03 MPC from year to year. Excess of fishery standards for nitrite ions in the water of the Kuibyshev reservoir for the period 2009-2015 yrs not found.

![Figure 3](attachment:image.png)

**Figure 3.** Long-term dynamics and trend of average annual concentrations of nitrite ions in the water of the Kuibyshev reservoir for the period 2009-2015 yrs, in multiplicities of MPC.
Analysis of fig. 4 shows that in the period 2009-2015 yrs in the water of the Kuibyshev reservoir, there was a noticeable tendency of growth in average annual concentrations of nitrite ions.

**Phosphate ions.** Long-term dynamics and trend of average annual concentrations of phosphate ions in the water of the Kuibyshev reservoir for the period 2009-2015 yrs is shown in fig. 5.

![Figure 4](image-url)

**Figure 4.** Long-term dynamics and trend of average annual concentrations of phosphate ions in the water of the Kuibyshev reservoir for the period 2009-2015 yrs, in multiplicities of MPC.

The average long-term concentration of phosphate ions for the period from 2009 to 2015 yrs amounted to 0.47 MPC. The maximum average long-term concentration of phosphate ions is 0.65 MPC was observed in 2013, and the minimum 0.28 MPC in 2009. On average, the concentration of phosphate ions grew by 0.02 MPC from year to year. Excess of fishery standards for phosphate ions in the water of the Kuibyshev reservoir for the period 2009-2015 yrs not found. In general, for the period considered, a moderate tendency of an increase in average annual concentrations of phosphate ions was observed in the water of the Kuibyshev reservoir.

Changes in the chemical composition of the water reservoir in retrospective years are given in Table 1.

| Period                                           | Nutrients, mg/l |   |   |   |
|--------------------------------------------------|-----------------|---|---|---|
| Volga river, 1952-1954 r.r. [14]                 | 0.015           | 0.001 | 0.18 | 0.02 |
| Period of formation of the Kuibyshev reservoir  | 0.043           | 0.004 | 0.32 | 0.06 |
| 1958-1959 r.r. [14]                              |                 |       |     |     |
| Period of stabilization of the Kuibyshev reservoir, 1960-1963 r.r. [14] | 0.034 | 0.003 | 0.34 | 0.06 |
| Period of stabilization of the Kuibyshev reservoir, 1964-1978 r.r. [14] | 0.023 | 0.013 | 0.3 | 0.06 |
| Morden period of the Kuibyshev reservoir, 2001-2005 r.r. [17] | 0.041 | 0.013 | 0.26 | 0.08 |
| Morden period of the Kuibyshev reservoir, 2009-2015 r.r. | 0.094 | 0.035 | 2.8 | 0.46 |

During the period of formation of the reservoir (1957-1959 yrs), there was an increase compared with 1952-1954 yrs the main nutrients are phosphate ions 2.9 times, nitrite ions 4 times, nitrate ions 1.8 times and ammonium ions 3.0 times.
In 1960-1963 during the period of stabilization of the reservoir, the content of nutrients was at a relatively low level.

In 1964-1978 compared to 1952-1954 the excess of phosphate ions was observed by 1.5 times, which is slightly lower than in previous years, at the same time a significant increase in nitrite ions was registered by a factor of 13. According to the content of nitrate ions and ammonium ions in the water of the reservoir, no significant dynamics was observed.

In 2001-2005 compared to 1952-1954 the growth of phosphate ions was registered by 2.7 times, ammonium ions by 4.0 times, which is slightly higher than in the previous period. The growth of nitrate ions was observed 1.4 times, which is slightly lower than in the previous period. The growth of nitrite ions was observed 13.0 times and did not change compared with the previous period.

It should be noted that in the modern period of 2009-2015 yrs marked a significant increase compared with 1952-1954 yrs and the previous period, the concentration of major nutrients - phosphate ions in 6.3 times, nitrite ions in 35.0 times, nitrate ions in 15.6 times and ammonium ions in 23.0 times.

4. Conclusions
The results of the analysis show that in 2009-2015 yrs the average annual concentrations of nitrate ions, nitrite ions, and phosphate ions in the water of the Kuibyshev reservoir did not exceed the fisheries standards.

During the period under review, the average annual concentrations of ammonium ions exceeded the fishery standards only in 2009 and 2010 in 1.37 and 1.50 times, respectively.

The trends of the dynamics of average annual concentrations of the studied nutrients in the water of the Kuibyshev reservoir were obtained, describing the general trends of these substances in time:

- moderate tendency to reduce the average annual concentrations of ammonium ions,
- weak growth trend of average annual concentrations of nitrate ions,
- moderate growth trend of average annual concentrations of phosphate ions,
- noticeable trend of growth in average annual concentrations of nitrite ions.

In order to improve the water quality of the Kuibyshev reservoir, it is necessary to reduce the nutrient load by reducing the diffuse discharge by treating wastewater and melt water from the territory of large industrial complexes located in the catchment area of the Kuibyshev reservoir, as well as afforestation and reforestation water protection zones. In addition, it is necessary to continue work on the further improvement of wastewater treatment of industrial and public utilities discharging into the Kuibyshev reservoir and its tributaries.

The obtained results can be used in planning measures to reduce the nutrient load on the waters of the Kuibyshev reservoir and its tributaries.

References
[1] Rosenberg G S and Vyhristiuk L A 2009 Volga basin: on the way to sustainable development (Tolyatty: Cassandra) p 477
[2] Latypova V Z and Ermolaev O P 2007 Kuibyshev reservoir: environmental aspects of water management (Kazan: Foliant) p 320
[3] Khuubaryan M G and Moiseenko T 2009 Bull. of the Russian Acad. of Sci. 79 403-410
[4] Minakova EA and Shlychkov A P et al 2018 Problems of regional ecology 6 92-97
[5] Minakova E A and Shlychkov A P et al 2014 SGEM 2014 2 641 - 649
[6] Datsenko Yu S 2007 Eutrophication of reservoirs: hydrological and hydrochemical aspects (Moscow: GEOS) p 232
[7] Seleznева A V 2007 Ecological rationing of anthropogenic load on water bodies (Samara: Samara Sci. Center of the Russian Academy of Sci.) p 107
[8] Minakova E A 2004 Accounting for meteorological factors in surface water quality management (on the example of the rivers Kazanka, Sviyaga, Stepnoi Zai) (St. Petersburg) p 147
[9] Minakova E A and Latypova V Z et al 2004 Environmental consulting 4 (16) 3-10
[10] Latypova V Z and Minakova E A et al 2005 Scien. notes of Kazan State Univ. 147 159-170
[11] Minakova E A and Latypova V Z et al 2001 Ecol chemistry 10 115-120
[12] Alekseev G A 1969 Meteorology and Hydrology 11 56-68
[13] Isaev A A 1988 Statistics in meteorology and climatology (Moscow: Moscow University Press) 245 p
[14] Monakov A V 1983 Kuibyshev reservoir (Leningrad: Science) 214 p
[15] Rosenberg G S and Vykhristyuk L A 2008 Kuibyshev reservoir (scientific and information reference book) (Togliatti: Instit. of Water Prob. of the Russian Academy of Sci.) 123 p