Features of the Modern Formation of Nutrient Load from the Urban and Rural Population on the Catchment Area of Water Bodies within the Borders of the Republic of Tatarstan

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Abstract. A comparative analysis of the formation of the nutrient load caused by the formation of communal discharges from the urban population and the dispersed load from the rural population for the period 2002-2015 yrs was carried out on the catchment of the Kuibyshev reservoir within the boundaries of the Republic of Tatarstan. It was revealed that the average value of the mass of nitrogen and phosphorus compounds formed in the catchment from municipal wastewaters of the urban population over the period is N_{tot} 5343 tons, P_{tot} 1790 tons; from the dispersed load of the rural population N_{tot} 515 tons and P_{tot} 207 tons. It is shown that the contribution of the nutrient load from municipal wastewaters of the urban and rural population is N_{tot} 96.3% and 3.7%, and according to P_{tot} 96.9% and 3.1%, respectively.

1. Introduction
At present, the excess intake of nutrients, which triggers the process of eutrophication of water bodies and watercourses, is a serious problem for most countries. Eutrophication is an increase in the biological productivity of water bodies as a result of the accumulation of nutrients in water [1]. Anthropogenic eutrophication is caused, in particular, by the discharge of nutrients with wastewater and surface runoff and differs from natural by the high rate of the process.

In recent decades, both national and international agreements on the reduction of nutrient discharges have been developed and standards for the discharge of nutrient pollutants have been developed [2]. The adopted Directive (Directive 91/271) is essentially binding on the countries of the European Community, but the choice of methods of environmental protection and ways of ensuring them is not regulated. Directive 91/271 establishes quality requirements for treated wastewater discharged into water bodies subject to eutrophication, depending on the number of conventional inhabitants of a settlement. In the Russian Federation, for the regulation of the content of nutrients, maximum permissible concentrations of pollutants (MPC) [3] are established, which regulate the quality of water in the design section of the river, located downstream of the stream at a distance of 500 m from the place...
of discharge of treated wastewater. Russian regulations are the strictest among the EU countries and Ukraine.

In connection with the deteriorating condition of water bodies, the assessment of the impact of urban wastewater as part of communal discharges, as well as the impact of a dispersed load from the rural population on water resources is a very urgent task necessary to develop management decisions to minimize the impact of nutrients on eutrophication of surface waters.

In this work, in continuation of a series of works on the assessment of biogenic pollution of the lowland reservoir in the European part of Russia [5-14], an assessment of the impact of the urban and rural population and isolation of their contribution to external biogenic pollution of the catchment area of the Kuibyshev reservoir within the Republic of Tatarstan was carried out.

2. Materials and methods

The calculation of the load on the private catchment area of the Kuibyshev reservoir, due to the input of nutrients from the urban and rural population, was carried out taking into account the recommendations given in [15].

Total nutrient load \( L_{\text{pop}} \) of total nitrogen \( N_{\text{tot}} \) and total phosphorus \( P_{\text{tot}} \), for the private catchment area of the Kuibyshev reservoir, formed by the urban and rural population, was calculated by the formula:

\[
L_{\text{pop}} = L_u + L_r
\]

where \( L_u \) - is the load generated by the urban population, tons per year; \( L_r \) - is the load generated by the rural population, tons per year.

When calculating the load on the private catchment area of the Kuibyshev Reservoir, due to the input of nutrients from the urban population according to formula (1), according to [16], it is assumed that one person releases \( P_{\text{tot}} = 2.5 \) gram per day from 1 person and \( N_{\text{tot}} = 13 \) gram per day from 1 person.

When calculating the load on the private catchment area of the Kuibyshev reservoir, due to the input of nutrients from the rural population according to formula (1), according to [17], it is assumed that \( P_{\text{tot}} \) is released by one person \( 0.60 \) gram per day from 1 person and \( N_{\text{tot}} = 1.49 \) gram per day from 1 person.

When calculating the load of inputs of phosphorus and nitrogen compounds from the urban population into the Kuibyshev reservoir, taking into account the functioning of existing biological treatment facilities, the purification efficiency was taken according to [18, 19] for phosphorus 30% and for nitrogen compounds - 60%.

3. Results and discussion

We have estimated the dynamics and trend of the load formed in the private catchment area of the Kuibyshev reservoir, due to the emission of \( P_{\text{tot}} \) and \( N_{\text{tot}} \) from the urban population, taking into account the efficiency of the treatment facilities (Fig. 1 - 2) and the dispersed load from the rural population (Fig. 3 - 4) for the period 2002-2015 yrs. In addition, we obtained regression equations describing the relationship between the load of nutrients \( P_{\text{tot}} \) and \( N_{\text{tot}} \) depending on the size of the urban and rural population.
Analysis of fig. 1 shows that the average value of the emission mass $P_{\text{tot}}$ from the urban population for the period 2002-2015 yrs amounted to 1790 tons. Maximum mass of emission $P_{\text{tot}}$ 1852 tons from the urban population was observed in 2015 yr and the minimum 1759 tons in 2002 yr. There was a high tendency for the growth of the emission mass $P_{\text{tot}}$ from the urban population, which on average increased by 7 tons per year.

Average value of emission mass $N_{\text{tot}}$ from the urban population for the period 2002-2015 yrs was 5343 tons. The maximum emission mass $N_{\text{tot}}$ from the urban population was observed in 2015 yr and amounted to 5527 tons, and the minimum 5247 tons in 2003 yr. On average, the mass of emission $N_{\text{tot}}$ from the urban population increased by 21 tons per year.
Figure 3. Dynamics and trend of load $P_{tot}$ on the catchment of the Kuibyshev reservoir from the rural population.

Analysis of fig. 3 shows the average value of the emission mass $P_{tot}$ from the rural population for the period 2002-2015 yrs amounted to 207 tons. Maximum mass of emission $P_{tot}$ from the rural population, 216 tons was observed in 2003 yr, and the minimum 200 tons in 2015 yr. On average, for the period under consideration, the mass of emission $P_{tot}$ from the rural population decreased by 1 ton per year.

Figure 4. Dynamics and trend of load $N_{tot}$ on the catchment of the Kuibyshev reservoir from the rural population.

Maximum emission mass $N_{tot}$ from the rural population 537 tons was observed in 2003 yr, and the minimum 498 tons in 2015 yr. The average value of the emission mass $N_{tot}$ from the rural population for the period 2002-2015 yrs in the waters of the Kuibyshev reservoir amounted to 515 tons. Analysis of fig. 4 shows that for the period 2002-2015 yrs there was a very high tendency towards a decrease in the mass of emission $N_{tot}$ from the rural population to the waters of the Kuibyshev reservoir, amounting to 2.4 tons per year.
Figure 5. Contribution of the load from wastewater of the urban population in the composition of communal discharges and the dispersed load from the rural population in the formation of nutrient load Kuibyshev reservoir within the boundaries of the Republic of Tatarstan, (P_{tot} and N_{tot}, %)

In general, the contribution of wastewater from the urban population in the composition of municipal discharges prevails over the impact of the dispersed load from the rural population and amounts to 96.9% for P_{tot} and 96.3% for N_{tot}, respectively (Fig. 5).

4. Conclusions
1. The magnitude, dynamics and trend of the nutrient load, formed on the catchment of the Kuibyshev reservoir within the boundaries of the Republic of Tatarstan, due to the input of P_{tot}, have been quantitatively determined and N_{tot} with municipal waste of the urban population, taking into account the efficiency of the treatment facilities. The average value of emissions from the urban population for the analyzed period was 1790 tons for P_{tot} and 5343 tons for N_{tot}. For the period 2002-2015yrs a high trend of increase in the emission mass P_{tot} and N_{tot} was noted (the values were 7 tons per year and 21 tons per year, respectively).

2. The magnitude, dynamics and trend of the nutrient load formed on the catchment of the Kuibyshev reservoir within the boundaries of the Republic of Tatarstan, due to the input of P_{tot}, have been quantitatively determined and N_{tot} from the dispersed load of the rural population for the period 2002-2015 yrs. A high trend of decrease in the mass of emission P_{tot} and N_{tot} was noted (the values were 1 tons per year and 2.4 tons per year, respectively). The average value of emissions in the catchment from the dispersed load of the population for the analyzed period was 207 tons for P_{tot} and 515 tons for N_{tot}.

3. Regression equations are obtained that describe the dependence of load variability P_{tot} and N_{tot} on the catchment of the Kuibyshev reservoir on the number of urban and rural population.

4. The contribution of the nutrient load from wastewater of the urban population in the composition of communal discharges and the dispersed load from the rural population to the formation of nutrient load of the Kuibyshev reservoir within the borders of the Republic of Tatarstan has been isolated. The contribution of the nutrient load from the wastewater of the urban population in the composition of communal discharges and the dispersed load from the rural population amounted to P_{tot} amounted to 96.9% and 3.1%, respectively. The contribution of the nutrient load from wastewater of the urban population in the composition of communal discharges and the dispersed load from the rural population amounted to N{tot} amounted to 96.3% and 3.7%, respectively.

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