

The Features of Eutrophication Processes in the Water of the Uzh River

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ABSTRACT

The chemical and hydrobiological analyses of water quality of the Uzh river of Korosten district and the city of Korosten of the Zhytomyr region were conducted. The influence of anthropogenic loads on the river eutrophication processes was estimated. The peculiarities of the course of eutrophic processes in the reservoirs of the Uzh river basin within the Korosten district and the city of Korosten were established. As a result of research, it was found that the phytoplankton in the surface waters of the Uzh river of Korosten district was represented by diatoms, as well as green, blue-green, euglenophytic, golden and dinophytic algae. Periods of their intensive reproduction were revealed for all departments of algae. Seasonal fluctuations in the content of biogenic elements of phosphorus and nitrogen dissolved in oxygen water, as well as their influence on the development of certain departments of algae were revealed. Statistical modelling of the processes of development of blue-green, and green algae as well as diatoms in the river Uzh of Korosten district on the average values of their content for less than three years was conducted. Changes in the qualitative and quantitative composition of algae during the year were used to build the models. The obtained experimental data and their revealed features were generalized in the form of linear and nonlinear statistical mathematical models of eutrophication processes. The general appearances of the functions that describe these processes; numerical values of the coefficients of the function and graphs were constructed as well as modeling errors were defined.

Keywords: eutrophication processes, water quality, phytoplankton, mathematical model.

INTRODUCTION

The water resources of small rivers play a significant role in the water supply of the region of each country (Pierzchała, 2020; Lusiana et al., 2019). It is known that in 2017 the Government of Ukraine presented the National Report “Sustainable Development Goals: Ukraine”, which covers the basic indicators for the achievement of seventeen Goals, taking into account the specifics of national development. In order to achieve Goal 6 “Clean water and adequate sanitation”, namely Target 6.3 “By 2030, improve water quality by reducing pollution, eliminating waste dumping and minimizing emissions of hazardous chemicals

and materials, halving the proportion of untreated wastewater and significantly increasing the recycling and safe reuse of wastewater worldwide” and Target 6.6. “By 2030, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes” research should be directed towards identifying the main sources of water pollution and possible environmental impacts. This will enable informed decisions to be made at the national level to prevent pollution of the hydrosphere.

Carrying out a comprehensive assessment of water management areas (river basins), substantiation of the allowable limit of anthropogenic impact on water resources is a necessary prerequisite

for solving environmental and economic problems. However, small rivers are much more polluted than large ones. They have a low stability and low self-cleaning potential and degrade at a faster rate (Delehan-Kokaiko et al., 2020; Lukiyanova, 2015; Carbajal Morán et al., 2021; Kharko & Matveeva, 2021; Szymanski et al., 2018).

The river Uzh of Korosten district is a tributary of the Teteriv river and the main source of water supply of the city (see Figure 1).

The wastewater from industrial enterprises and agricultural lands enters the river from the adjacent territories. Pollution of its waters occurs due to the clutter of coastal strips with landfills for household and construction waste and the unsatisfactory condition of most treatment facilities. As a result, the river is polluted with nutrients (nitrogen and phosphorus compounds) (Quevedo et al., 2011; Kharytonova & Khrutba, 2021). This is the cause of a number of such problems, namely, the uncontrolled increase in the biomass of phyto- and zooplankton, higher aquatic plants and the disturbance of the natural balance of biological productivity, which is a consequence of eutrophication. As a result of such anthropogenic load, the physicochemical properties of water deteriorate (Kharytonova and Khrutba, 2021). At the same

time, water blooms, an increase in the number of blue-green algae, the appearance of unpleasant taste and odor, and increased acidity should be expected; these will lead to the impossibility of using this water for household purposes and for recreational purposes (Lukianova, 2015).

According to the Council Directive of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC), the implementation of its provisions provides monitoring of surface and groundwater pollution by nitrate and phosphate compounds, eutrophication of surface waters, assessment of the impact of action plans on water quality and methods of agricultural production.

The aim of the study was to establish the peculiarities of eutrophic processes in the reservoirs of the Uzh River basin within the Korosten district, the impact of anthropogenic pressures on the eutrophication of the river, and justification of the measures to address the problems.

The paper analyzed and used the results of scientific research presented in the collection “State Water Cadastre. Annual land surface water quality data. Part 1. Rivers and canals. 2001–2013”. In addition, the results of laboratory studies of water quality were used.

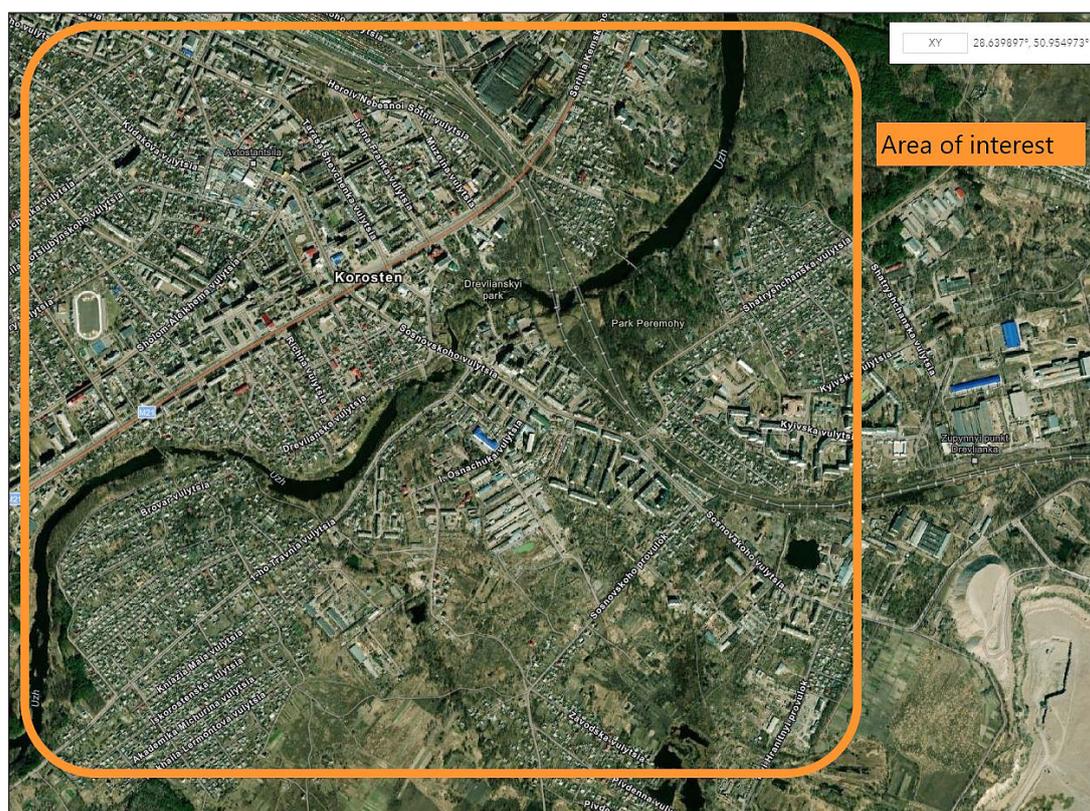


Figure 1. Area of interest

MATERIAL AND METHODS OF RESEARCH

In the process of research, the analysis of water quality indicators of the river was performed according to the three most informative indicators of the degree of eutrophication of the reservoir, namely: the content of phosphorus, nitrogen, and dissolved oxygen for 2018–2021. Hydrochemical, hydrobiological and radiological observations of the river within the city of Korosten were conducted quarterly. The surface water quality was controlled by the following indicators: odor, transparency, color, dissolved oxygen, nutrients (phosphorus, nitrogen) in the form of phosphates, nitrates and nitrites. These are indicators that are used to assess and control the degree of water eutrophication. Determination of phosphates, nitrates, nitrites and dissolved oxygen in water was performed according to the generally accepted methods (Nollet and De Gelder 2013; World Health Organization, 2006; National Primary Drinking Water Regulation Table, 2009).

Among the hydrobiological indicators, the composition and number of phytoplankton was determined. Phytoplankton sampling for monitoring was performed in parallel with the selection of hydrochemical samples. Observations covered all biological seasons. Determination of the qualitative and quantitative composition of algae in the Uzh River was performed by hydrobiological analysis. The main method of analysis involved determining the concentration of phytoplankton on membrane filters № 6 and subsequent counting of the amount of algae in the Najott chamber.

The selected water samples were analyzed using standard methods and metrologically verified

equipment (National Primary Drinking Water Regulation Table, 2009). The reliability of the results and conclusions is ensured by a satisfactory coincidence of theoretical models with the results of experimental studies, as well as laboratory control of errors in the composition of the samples.

RESULTS AND DISCUSSION

As a result of research, it was found that the phytoplankton in the surface waters of the Uzh River is represented by Cyanophyta, Bacillariophyta, Chlorophyta, Euglenophyta, Dinophyta and Crysophyta algae. The studies conducted over three years have shown that the reservoir is dominated by: Cyanophyta (93.6%), Bacillariophyta (3.4%) and Chlorophyta (2.8%) algae. Euglenophyta, Dinophyta and Crysophyta are found in small quantities, so they are not crucial to the impact on the indicators that characterize the toxicity of the aquatic environment. During these years, characteristic differences in the intensity of reproduction of individual phytoplankton forms were observed (see Figure 2).

Periods of their intensive reproduction were revealed for all departments of algae. Thus, the mass reproduction of blue-green algae occurs in late June to November, taking the maximum value in August (198503 cells/cm³). Blue-green algae do not play a large role in the spring blooming of water (April-May), the bulk of them appear only in the second half of summer and disappear with the onset of cooler weather in December. Green algae begin to settle in the reservoir in late May. Mass reproduction is achieved in June

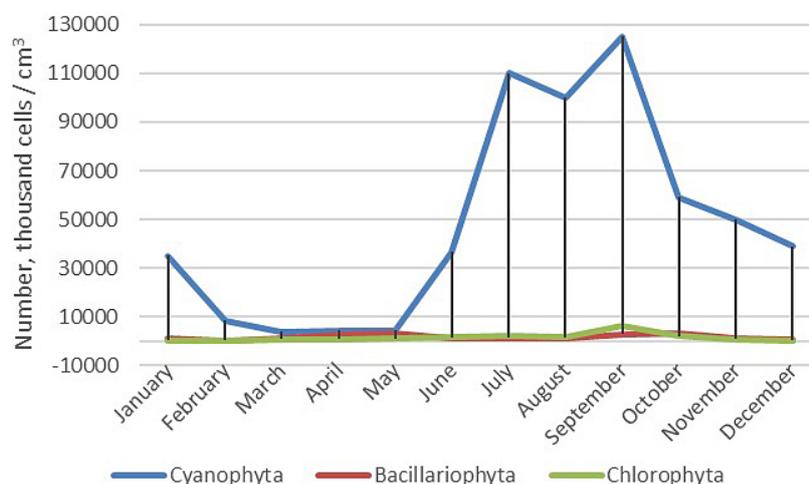


Figure 2. Dynamics of development of the main departments of algae in the Uzh river

(1673 cells/cm³). In December, there is a significant decrease. Diatoms are found in the waters of the river at all times of the year and have two periods of mass reproduction. The first period is from April to June (4256 cells/cm³), and the second - from September to November (3982 cells/cm³) (Stephanodiscus, Melosira, Nitzschia, Fragilaria).

A study of the content of dissolved oxygen in the water of the reservoir of the river by seasons of the year, revealed a clear decrease in this indicator in the period when the mass increase in the number of blue-green algae begins (see Figure 3). This period (April-October) is also characterized by a slight decrease in the number of diatoms and an increase in green algae. Thus, it is the blue-green algae that cause water pollution in summer.

The reduction of dissolved oxygen in water begins in April. Subsequently, in June there is a sharp decrease in soluble oxygen to levels of 6.9 mgO₂/dm³. At this time, the number of blue-green algae begins to increase. This decrease in the content of dissolved oxygen lasts until September, after which the content of the latter gradually

increases, and in December it reaches its maximum value (9.4 mgO₂/dm³). In order to prevent eutrophic processes, there is a need to monitor the dynamics of the content of nutrients nitrogen and phosphorus and to monitor the main cycles of phytoplankton development (see Figure 4).

Studies have shown that nitrates and phosphates not only effect the development of phytoplankton, but are also related in some way. The calculation of correlation coefficients ($R^2 = 0.5800$) revealed a fairly close relationship between nitrite and phosphate concentrations in reservoirs during the year. The explanation of this phenomenon is based on the determination of the peculiarities of the interaction between these compounds. It is known that the combined action of nitrogen and phosphorus stimulates the development of phytoplankton more than the action of each of these nutrients separately. In addition, it was found that phosphorus plays a regulatory role in the formation of production. Increasing its content in water promotes more complete use of nitrogen by algae. Phosphorus can be considered



Figure 3. Average values of dissolved oxygen concentration for 2018–2021 in the Uzh river

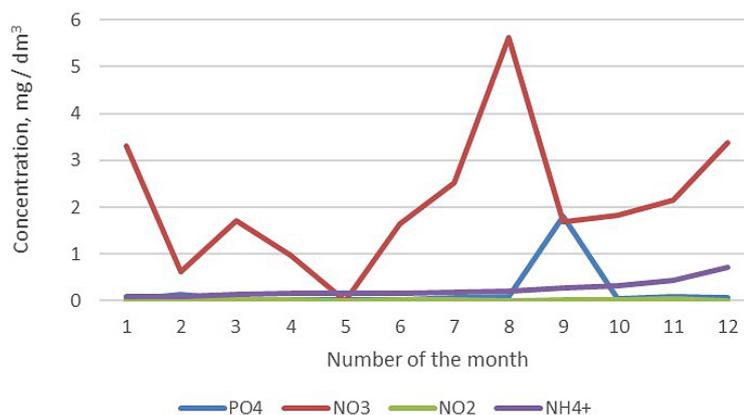


Figure 4. The average values of nitrite, nitrate, phosphate concentrations in the Uzh river

a major factor in the eutrophication of water bodies. Without it, even with the enrichment of the aquatic environment with nitrogen, eutrophic processes are significantly weakened.

In this regard, the issue of modeling the development of algae and eutrophic processes in water bodies deserves special attention (Mateus et al., 2014). Modeling of the processes that characterize the intensity of the increase in the number of algae will not only make predictions about the further development of algae and their impact on the overall toxicity of water in the river, but also allow timely measuring of eutrophication (Shourian et al., 2016; Fadel et al., 2019).

Statistical modeling of phytoplankton development processes was used. In order to build the models, data were used that characterize the eutrophic processes occurring in the river. Such indicators are changes in the qualitative and quantitative composition of algae during the year. The obtained experimental data and their revealed features are generalized in the form of linear and nonlinear statistical mathematical models of eutrophication processes. The general form of the functions describing these processes was defined; numerical values of the coefficients of the function; graphs was constructed and modeling errors was determined (Nykyforov et al., 2016).

Statistical modeling of the processes of development of blue-green and green algae as well as diatoms on the average values of their content for less than three years was conducted. Mathematical models are based on the study of causal relationships between environmental conditions and phytoplankton productivity (Gaard et al., 2011).

As a result of constructing a statistical mathematical model, the coefficients of the polynomial approximating the experimental data were

determined. Function (1) describes the general behavior of the change of indicators, which is performed by approximating their number by polynomials of the k -th degree:

$$K_1 = a_0 + \sum_{i=1}^k a_i N_m^i \quad (1)$$

where: K_1 – the number of algae cells, cells/cm³; N – number of the month; a_0, a_i – coefficients of the polynomial of the i -th month; k – the degree of the polynomial.

In order to study the changes in the concentrations of diatoms and green algae, their number was approximated by a polynomial of degree 6 and the coefficients of the polynomial that approximate the experimental data were determined.

According to the results of the approximation, the regression equation is described, which describes the dynamics of changes in the quantitative composition of diatoms (formula 2) and the approximating curve (see Figure 5):

$$y = 0.7607x^6 - 31.557x^5 + 506.18x^4 - 3936.7x^3 + 15156x^2 - 25808x + 15216 \quad (2)$$

and the correlation reliability is equal to $R^2 = 0.8108$.

The regression equation describes the dynamics of changes in the quantitative composition of green algae (formula 3) and the approximating curve (see Figure 5):

$$y = 0.759x^6 - 28.287x^5 + 401.74x^4 - 2736.2x^3 + 9249.2x^2 - 14077x + 7555.2 \quad (3)$$

and the correlation value is equal to $R^2 = 0.7106$.

In order to study the changes in the concentrations of blue-green algae, an approximation of

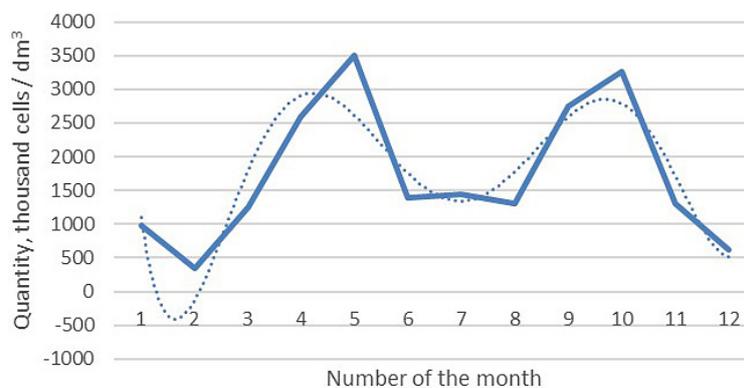


Figure 5. Approximation of diatom development processes: dashed line – experimental data, solid line – approximation of experimental data

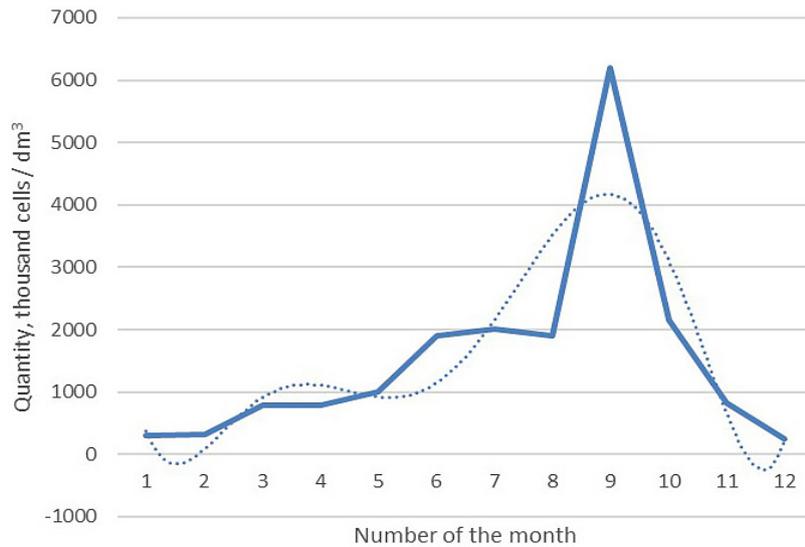


Figure 6. Approximation of green algae development processes: dotted n line – experimental research data, solid line – experimental data approximation

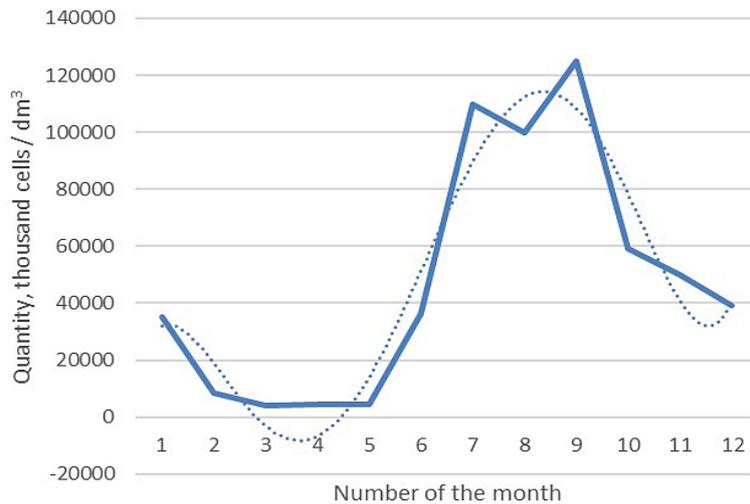


Figure 7. Approximation of blue-green algae development processes: dotted line – experimental data, solid line – experimental approximation

their number by a polynomial of degree 5 (see Figure 7) and the regression equation describes the dynamics of changes in the quantitative composition of blue-green algae (formula 4):

$$y = 54.46x^5 - 1680.5x^4 + 17771x^3 - 73951x^2 + 107945x - 18160 \quad (4)$$

and the correlation reliability is equal to $R^2 = 0.9063$.

Correlation and factor analysis of eutrophication processes of the Uzh river was carried out. The factor analysis consisted of: the study of pairwise regression, the selection of factors influencing the development of algae of different departments and the construction of a multiple

model that takes into account the combined influence of factors.

It was investigated that the main influencing factors for blue-green algae are the combined effect of phosphate concentration and temperature ($R^2 = 0.86$; $R^2 = 0.74$), nitrite concentration and temperature ($R^2 = 0.72$; $R^2 = 0.51$), nitrate concentrations and temperatures ($R^2 = 0.70$; $R^2 = 0.48$); for diatoms – the combined effect of nitrite concentration and temperature ($R^2 = 0.77$; $R^2 = 0.59$), and phosphate concentration with ammonia ($R^2 = 0.77$; $R^2 = 0.59$); for green algae – similar indicators as for blue-green algae ($R^2 = 0.62$; $R^2 = 0.39$), ($R^2 = 0.61$; $R^2 = 0.38$), ($R^2 = 0.62$; $R^2 = 0.38$) respectively).

CONCLUSIONS

The studies have shown that the ecological condition of the Uzh river is satisfactory. On the basis of the conducted studies and the obtained data it is possible to draw a conclusion that during a year there are changes in intensity of reproduction of separate phytoplankton forms. The periods of increased eutrophication due to blue-green, diatomaceous and green algae are especially threatening in relation to the ecological safety of the Uzh river.

The proposed statistical models should be used as a basis for forecasting eutrophication processes and developing practical tools to improve the environmental safety of the reservoir.

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