Eutrophication Potential of the System: "Catchment Area - Water Body" as a Measure of Sustainable Development of the Aquatic Ecosystem

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Abstract. A method is proposed for assessing nutrient pollution flows in the catchment - water body system, based on the following indicators: the eutrophication potential of the catchment area and water body, the eutrophication potential of diffuse pollution of the catchment area of a water body, the potential for retaining biogenic pollution in the catchment area of a water body. The components of the eutrophication potential for the catchment area of the river Kazanka, located in the left - bank of the Kuibyshev reservoir. It has been established that the eutrophication potential of the catchment area and the waters of the river Kazanka for nitrogen and phosphorus compounds is 2259 and 170 and 705 and 56 t • year⁻¹, respectively. It is shown that the potential for retaining nutrient pollution in the catchment area of the river Kazanka of nitrogen and phosphorus compounds is 69 and 67%, respectively.

1. Introduction
To define the vector of human development at the Conference on Environment and Development in Rio de Janeiro (1992), the Brundtland Commission proposed the term sustainable development - development that meets the needs of the present and does not jeopardize the ability of future generations to satisfy your own needs. Water management, like no other field of activity, is systematically linked to all aspects of sustainable development. A special role in this belongs to the problems of water use, water protection and protection from pollution, anthropogenic accidents, natural disasters, catastrophes and other negative phenomena caused by hydrological processes [1]. Modern trends in environmental management indicate the need for real steps towards sustainable development of territories and, as a consequence, the transition from the global and national levels of solving sustainable development problems to regional and local levels. There is also a need for a detailed analysis of the immediate and more distant prospects for the implementation of programs for achieving sustainable development with more obvious assessments of the effectiveness of the planned activities [2].

In modern conditions, the processes of transformation in aquatic ecosystems proceed much faster than before, since they are caused not so much by natural factors acting on the scale of geological time as by anthropogenic ones. Such high rates of anthropogenic transformation of the environment today
often lead to irreversible changes in aquatic ecosystems. The process of anthropogenic eutrophication, which covered many water bodies of the world and caused a deterioration in the quality of surface waters, can be attributed to the number of global processes, a sharp increase in the rate of which has been noted in recent decades [3]. When studying the state of eutrophication of the water ecosystem, the primary issue is to assess the formation of nutrient elements in the catchment of a water body for a thorough study of the mechanisms of formation of nutrient pollution [4] and preparation of management decisions aimed at improving the ecological situation of a complex ecosystem «catchment - water body».

The aim of the study is to determine the main mechanisms for the formation of flows of nutrients in a complex system of water body catchment - water body.

This article is a continuation of the series of works by the authors [5-10] devoted to the assessment of the formation of nutrient pollution of water bodies.

2. Materials and methods

In this work, we used information on the discharge of nutrients into watercourses of the Republic of Tatarstan, presented in the State Statistical Reporting "Information on Water Use" for 2008-2016 yrs. Discharges of ammonium nitrogen, nitrates, nitrites and phosphates were evaluated as nutrients in the work. The work used data from the Department of Hydrometeorology and Environmental Monitoring of the Republic of Tatarstan for the period 2008-2016 yrs. As input data for assessing atmospheric deposition of nitrogen and phosphorus compounds on the surface of the catchment for the period 2008-2016 yrs. The materials of the Federal State Institutions of Roshydromet (FGBU Roshydromet) used in the basin of the Middle and Lower Volga were used. Materials of the Ministry of Agriculture and Food of the Republic of Tatarstan on the use of mineral fertilizers for agricultural crops, as well as their own experimental materials on water consumption and pollution.

To obtain comparable information, the processing of observations of water pollution in the Kuibyshev reservoir was carried out using the regulatory and methodological documents used in the monitoring system of the Federal State Budgetary Institution of Roshydromet, as well as the methods of physical and statistical analysis given in [11, 12]. To determine the structure of the underlying surface of the studied basin, the results of interpretation of the Landsat-8 satellite images for the summer and autumn months of 2017 year were obtained using the US Geological Survey web service.

The mechanism of formation of the eutrophication potential of the catchment-water body system, including the catchment area of the Kuibyshev reservoir, taking into account the proposed indicators, is presented in the form of a structured diagram in Fig. 1.

To assess the flux of nutrients caused by natural and anthropogenic factors in a complex ecosystem, a catchment - a water body, we propose indicators:

- **Eutrophication potential of a water body's catchment area** (EP<sub>wa</sub>) is the predicted value of the total mass of nutrient elements (nitrogen and phosphorus) formed as a result of the actual impact of an integral complex of organized and nonpoint nutrient emission from natural and anthropogenic factors on the catchment area of a water body, which determine the level of possible pollution of a water body in a given geographic area (t • year<sup>-1</sup>).

- **Eutrophication potential of diffuse pollution of the catchment area of a water body** (EP<sub>ant</sub>) is the total mass of nutrient elements (nitrogen and phosphorus) formed as a result of the actual impact of sources of emission of pollutants dispersed over the catchment area of a water body as anthropogenic (surface runoff from urbanized areas, industrial sites, agricultural land, atmospheric fallout) and natural origin (geological structure, landscape features, water and wind erosion processes, soil types, forest cover, etc.), which determine the level of possible pollution of a water body in a given geographical area (t • year<sup>-1</sup>).
**Figure 1.** The mechanism of eutrophication potential formation «catchment - water body» systems.

**Potential for retention of nutrient pollution in the catchment area of a water body** (PR) is the total mass of nutrient substances in the catchment area of a water body, assimilated by natural factors or minimized (neutralized) by modern scientific and technical means and methods (introduction of best available technology, science-intensive technologies to minimize wastewater, introduction of modern nutrient treatment facilities, etc.) in a given geographic area (t • year\(^{-1}\)).

**Assimilation potential of nutrient elements retention by the drainage area of a water body** (PR\(_{\text{ass}}\)) is the mass of nutrient elements (nitrogen and phosphorus) retained, mineralized, neutralized and transformed by natural factors of the hydrographic network of a water body's drainage area, as well as taken out of it per unit of time, (t • year\(^{-1}\)).

**Innovative potential for the retention of nutrients by the catchment area of a water body** (PR\(_{\text{inn}}\)) is the total mass of nutrients (nitrogen and phosphorus), minimized by introducing scientific and technical environmental protection measures (the most advanced technological solutions for wastewater treatment, optimization of agricultural production, removal of nutrients from crop yield, application of the best available technologies (BAT), etc.) at the current point in time, (t • year\(^{-1}\)).

**Eutrophication potential of point pollution of the catchment area of a water body** (EP\(_{p}\)) - total mass of nutrients coming directly to a water object from point sources at a given moment of time, which determines the level of possible contamination of a water object in these geographical conditions, (t • year\(^{-1}\)).

**Eutrophication potential of a water body** (EP\(_{w}\)) is the predicted value of the mass of nutrient elements (nitrogen and phosphorus) entering the water body directly from point sources, as well as with surface runoff from the catchment area of a water body, representing the residual amount of the total mass of nutrient substances formed on catchment area of a water body and transformed, minimized by natural and anthropogenic factors, causing the level of possible pollution of the water body, in the given geographical conditions, (t • year\(^{-1}\)).

The eutrophication potential of a water body’s catchment area is quantified by the sum of the factorial diffuse load, calculated in accordance with formula (1):

\[
\text{EP}_{\text{diff}} = L_{\text{ag}} + L_{\text{atm}} + L_{\text{lc}} + L_{\text{l}} + L_{\text{c}}
\]  

(1)
EP\textsubscript{diff.} – eutrophication potential of diffuse pollution of the catchment area of a water body, (t \cdot year\(^{-1}\));
L\textsubscript{ag} - load of nutrients from agricultural land (reclaimed and non-reclaimed land), (t \cdot year\(^{-1}\));
L\textsubscript{ann} - load of nutrients with atmospheric precipitation on the catchment, (t \cdot year\(^{-1}\));
L\textsubscript{s} - load of nutrients from settlements, (t \cdot year\(^{-1}\));
L\textsubscript{lk} - load of nutrients from livestock complexes, (t \cdot year\(^{-1}\));
L\textsubscript{I} - load of nutrients with removal from different types of natural landscapes, (t \cdot year\(^{-1}\)).

The potential for retention of nutrient pollution in the catchment area of a water body is quantified by the sum of the factorial retention potentials calculated in accordance with the formula (2):

\[ \text{PR} = (\text{PR}_{\text{ass}} + \text{PR}_{\text{inn}}) \]  

\( \text{PR} \) – potential for retention of nutrient pollution by the water body catchment area, (t \cdot year\(^{-1}\));
\( \text{PR}_{\text{ass}} \) – assimilation potential of nutrient elements retention by the drainage area of a water body, (t \cdot year\(^{-1}\));
\( \text{PR}_{\text{inn}} \) – innovative potential for the retention of nutrients by the catchment area of a water body, (t \cdot year\(^{-1}\)).

The value of the eutrophication potential of a water body is calculated by the formula (3):

\[ \text{EP}_w = (\text{EP}_{\text{diff.}} - \text{PR}) + \text{EP}_p, \]  

\( \text{EP}_w \) – eutrophication potential of a water body, (t \cdot year\(^{-1}\));
\( \text{EP}_p \) – eutrophication potential of point pollution of the catchment area of a water body, (t \cdot year\(^{-1}\)).

3. Results and discussion

Catchment of the river Kazanka, is located in the left-bank part of the Kuibyshev reservoir. The river basin is confined to the south western slope of the North of the Republic of Tatarstan and is located in the southwestern part of the Kama-Vyatka artesian basin. The entire catchment area of the river Kazanka is located on the territory of the Republic of Tatarstan within the Kuibyshev reservoir. The total length of the river is 172 km, the basin area is 2714 km\(^2\). In the basin of the river Kazanka are the largest industrial enterprises of the Republic of Tatarstan, the water resources of the river Kazanka are used for the needs of industry, agricultural water supply, recreation and irrigation [7].

The main results of the assessment of the eutrophication potential of the catchment area and water body on the example of a pilot object - the catchment of the river Kazanka, located in the left-bank part of the Kuibyshev reservoir are given in table. 1.

Table 1. Indicators of the eutrophication potential of the catchment area and water body on the example of a pilot object - the catchment of the river Kazanka.

| Eutrophication potential indicators catchment-water system | N\textsubscript{tot} (t \cdot year\(^{-1}\)) | P\textsubscript{tot} (t \cdot year\(^{-1}\)) |
|----------------------------------------------------------|------------------------------------------|
| Eutrophication potential of the catchment area of the river Kazanka | 2259 | 170 |
| Potential for retention of biogenic pollution by the catchment area of the river Kazanka | 1554 | 114 |
| Eutrophication potential of the catchment area of the river Kazanka | 705 | 56 |

Analysis of the table. 1 shows that the eutrophication potential of the catchment area of the river Kazanka for nitrogen and phosphorus compounds, respectively, is 2259 and 170 t \cdot year\(^{-1}\), and the eutrophication potential of the river Kazanka for the same nutrient elements is, respectively, 705 and 56 t \cdot year\(^{-1}\). The potential for retention of nutrient pollution in the catchment area of the river Kazanka for nitrogen and phosphorus compounds is 1554 and 114 t \cdot year\(^{-1}\), respectively. Thus, the
catchment area of the river Kazanka holds 69 and 67% of nitrogen and phosphorus compounds, respectively.

4. Conclusions
1. A method is proposed for assessing nutrient pollution flows in a complex system of a complex system "catchment - water body", based on the following indicators: eutrophication potential of the catchment area and water body, eutrophication potential of diffuse pollution of the catchment area of a water body, potential for retaining nutrient pollution by the catchment area of a water body.

2. The estimation of eutrophication potential of catchment area of the pilot facility - catchment area of the river Kazanka, located in the left-bank part of Kuibyshev reservoir. Calculated values of nitrogen and phosphorus compounds are 2259 and 170 t • year⁻¹, respectively.

3. Calculation of nutrient pollution retention potential in the catchment area of the river Kazanka has been carried out taking into account assimilation and innovative potential of nutrient elements retention. Its value for nitrogen and phosphorus compounds was 1554 t • year⁻¹ and 114 t • year⁻¹, respectively, which is 69 and 67% of the eutrophication potential of the catchment area of the river Kazanka.

4. Calculation of the eutrophication potential of the river Kazanka showed that 31% of the mass of nitrogen compounds and 33% of phosphorus compounds formed in the catchment area of the river Kazanka reaches the surface waters of the river.

5. The proposed indicators: eutrophication potential of a water body's catchment area; eutrophication potential of diffuse pollution of the catchment area of a water body; potential for retention of nutrient pollution in the catchment area of a water body; assimilation potential of nutrient elements retention by the drainage area of a water body; innovative potential for the retention of nutrients by the catchment area of a water body; eutrophication potential of point pollution of the catchment area of a water body; eutrophication potential of a water body. Their use allows identifying sources that make the main contribution to nutrient pollution of water bodies, organizing a monitoring system on a qualitatively new level and preparing sound management decisions aimed at reducing nutrient pollution of water bodies and sustainable management of water ecosystems.

5. References
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