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Journal of Ecology and Natural Resources
ISSN: 2578-4994

An Optimization Approach to Wastewater Discharge Regulation in Ukraine during the Post-War Reconstruction Period

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Short Communication

Volume 10 Issue 4

Received Date: October 18, 2026

Published Date: October 30, 2026

DOI: 10.23880/jenr-16000428

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Abstract

This article argues for the feasibility of an optimization approach to setting standards for pollutant discharges with wastewater into small rivers during Ukraine's post-war reconstruction. It is emphasized that the approach adopted in Ukraine to wastewater discharge standards differs from the pan-European approach. However, European water legislation allows for the specific conditions of individual countries to be taken into account. In addition to natural and economic factors, Ukraine will face increased river pollution due to hostilities. An optimization task is presented, the solution of which will result in optimal quantitative and qualitative characteristics of wastewater treatment.

Keywords: Wastewater; Pollutant; Optimization Task

Short Communication

In economically developed countries, one of the main areas of environmental protection is regulating natural resource use. For this reason, standards for pollutant discharges with wastewater are established for water-using enterprises. The purpose of establishing these standards is to conserve and restore water resources.

The approach to wastewater disposal standards adopted in Ukraine differs from the pan-European approach. In most European countries, standards are developed based on existing wastewater treatment technologies. Specifically, best-available-techniques technical standards are established for various types of wastewater depending on the type of production . This principle is partially reflected in Ukrainian water legislation for municipal enterprises with a full biological treatment cycle, based on biological oxygen demand, chemical oxygen demand indicators, and concentration of suspend. However, in general, the calculation of standards is based on a direct calculation of the mass of a substance whose discharge does not result in exceeding permissible standards.

In the authors' opinion, the existing principle should be maintained in Ukraine in the coming years for the following reasons:

Ukraine is geographically the largest country in Europe, with significant regional differences in both natural and climatic conditions and economic activity. This complicates

environmental safety management and does not allow copying water protection legislation from other countries.

- Ukraine is one of the countries in Europe with the least water resources.
- The existing approach to regulation has been in effect in Ukraine since 1990 and is generally consistent with general water protection legislation.
- Ukraine has a high level of deterioration in its wastewater treatment systems, many of which have been in operation since Soviet times.

Maintaining the existing methodological framework does not conflict with European environmental legislation. Article 13 of Directive 2000/60/EC [1] indicates that specific features exist in different countries and must be taken into account. National programs therefore retain priority in determining water protection policies.

However, during the post-war reconstruction period, Ukraine will face additional challenges. On the one hand, there is a shortage of financial resources. On the other hand, there is river pollution due to military action. This pollution is caused, firstly, by direct water contamination from toxic substances in munitions and fuel from deactivated equipment, and secondly, by the release of pollutants into rivers due to the destruction of industrial facilities.

The problem will be especially significant for small rivers due to their low assimilative ability.

Therefore, the authors believe it is appropriate to return to the optimization approach to calculating wastewater discharge standards into small rivers. This approach was mandatory in Ukraine from 1990 to 1994. However, due to its imperfections, it ceased to be widely used. First of all, it did not allow for variation in wastewater treatment efficiency, which is possible in some cases [2,3]. The articles [4-7] refined the optimization approach, eliminating existing shortcomings.

The optimization approach is based on the idea that various alternative purification routes may exist. Each route is characterized by its technological and economic characteristics. Some routes may actually exist at the time the optimization problem is being solved, while others do not, but could be created if it proves profitable.

Then the objective function has the form:

$$Z = \sum_{i=1}^{m} \sum_{r=1}^{R_i} \left(f_e\left(\{x_{irj}\}, \{q_{ir}\}\right) + \frac{f_c\left(\{x_{irj}\}, \{q_{ir}\}\right)}{31536 \cdot T_{ir}} \right) \rightarrow \min , \quad (1)$$

where { } is the designation of the array; fe, fc are the functional dependencies of the operating (UAH/m3) and capital (thousand UAH) costs of treatment, respectively; j is the pollutant index; i, m are the index and the number of wastewater treatment outlets, respectively; r, Ri are the index and the number of process routes for wastewater treatment in the i-th outlet, respectively; xirj is the concentration of the pollutant after treatment; qir is the flow rate of wastewater; Tir is the duration of the treatment facilities on the corresponding route, in years.

The variables to be optimized are arrays $\{x_{irj}\}, \{q_{ir}\}$.

The limitations of the optimization problem are determined by the principle of non-deterioration of the existing quality of river water and the need to achieve the quality standards of natural water at the controls sections:

$$\begin{cases} y_{jk} \le L_j, \; j = 1 \div n, \; k = 1 \div K; \\ x_j \le C_j^f, \; j = 1 \div n, \; i = 1 \div m; \\ x_j \ge L_j, \; j = 1 \div n, \; i = 1 \div m; \\ \sum_{r=1}^{R_i} q_{ir} = q_i, \; i = 1 \div m; \end{cases} \quad (2)$$

where k, K are the index and quantity of the controls sections, respectively; L is the limit concentration of the substance in natural water; C_{ij}^f is the factual concentration of the substance in the wastewater, mg/dm3. ykj is the calculated concentration of the substance in the controls sections, mg/dm3.

Without loss of generality, it is assumed that the actual concentrations of pollutants in wastewater exceed the limit concentration. Otherwise, the corresponding quantities are treated as constants, and only the dimensionality of the problem is reduced.

At the same time, in the conditions of a market economy, it is necessary to solve the problem of fair distribution of funds for water purification among water users. The monetary contribution of each water user must be proportional to the mass of pollutants discharged with wastewater:

$$S_i = p \cdot \sum_{j}^{N_j} \mu_j \cdot M_j^i , \quad (3)$$

where Si is the monetary contribution of the i-th water user; μj is the weighting coefficient taking into account the cost of cleaning the j-th pollutant; Nj is the quantity of pollutants in the wastewater of the i-th water user; p is the proportionality coefficient; Mij – mass of j-pollutant in wastewater.

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Proportionality coefficient p is found by the formula:

$$p = \frac{S}{\sum_{i}\sum_{j}^{N_j} \mu_j \cdot M_j^i}, \quad (4)$$

where S is the total cost of cleaning products.

Conclusion

The described optimization problem allows us to determine the optimal quantitative and qualitative characteristics of wastewater treatment. This will ensure the environmental safety of wastewater discharges into small rivers with minimal economic costs. The results of the study are useful during the post-war reconstruction of Ukraine.

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