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Influence of financing water protection measures in the field of transport on water quality of water bodies

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ABSTRACT Transport is a major water consumer and source of environmental pollution, including water resources. In order to preserve and improve water quality in water bodies at industrial and transport enterprises, including railway enterprises, water protection measures entailing permanent significant funding are required.

The study is aimed to develop a methodology for determining dependence of water quality of the water body on the real financing of water protection measures; theoretical justification of the choice of water quality of the water body from the quality of wastewater (WW) of water users, discharging them into the water body and amount of financing of water protection measures.

The solution of the task of determining the best water quality in a water body under limited financing of water protection measures and rational distribution of financial resources between water users, including transport infrastructure objects, is proposed.

Financing of water protection measures in Russia is less than abroad and has been decreasing over the last three decades. The limits for pollutant concentrations in pollutant discharges into water bodies and water disposal systems in Russia are often set very strict, sometimes more stringent than those for drinking water, which leads to unjustified spending of investment costs.

It is pointed out that at present in Russia market relations in the field of nature and, in particular, water use have not been formed. The basic difficulties at realization of these relations in our country are designated.

When using the proposed methodology, the rational quality of water resources of water users by limiting pollutants and the rational distribution of funds for water protection measures among water users within the limited amount of financing are determined. The extent to which water quality in a water body changes is also determined. The possibility of practical application of the proposed methodology is considered.

KEYWORDS: financing of water protection measures; water quality; water body; water user; transport infrastructure; water purity index; pollution concentration; environmental performance index; maximum permissible discharge

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Научная статья

Влияние финансирования водоохранных мероприятий в сфере транспорта на качество воды водных объектов

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АННОТАЦИЯ Транспорт является крупным водопотребителем и источником загрязнения окружающей среды, включая водные ресурсы. Для сохранения и улучшения качества воды в водных объектах на промышленных и транспортных предприятиях, в том числе железнодорожных, необходимо проводить водоохранные мероприятия, которые требуют постоянного значительного финансирования.

Цель исследования — разработка методики определения зависимости качества воды водного объекта от реального финансирования водоохранных мероприятий; теоретическое обоснование выбора состояния качества воды водного объекта от качества сточных вод (СВ) водопользователей, сбрасывающих их в водный объект, и от объема финансирования водоохранных мероприятий.

Предложено решение задачи определения наилучшего качества воды в водном объекте при ограниченном объеме финансирования водоохранных мероприятий и рациональном распределении финансовых средств между водопользователями, в том числе объектами транспортной инфраструктуры.

Финансирование водоохранных мероприятий в России меньше, чем за рубежом, за последние три десятилетия оно снижается. Предельные нормы концентраций загрязняющих веществ (ЗВ) в СВ при сбросе их в водные объекты и в системы водоотведения в России часто устанавливаются очень жесткие, иногда более жесткие, чем к питьевой воде, что ведет к неоправданному расходованию инвестиционных затрат.

Указано, что в настоящее время в России не сформировались рыночные отношения в области природо- и, в частности, водопользования. Обозначены основные трудности при реализации этих отношений в нашей стране.

При использовании предложенной методики определяется рациональное качество СВ водопользователей по лимитирующему ЗВ и рациональное распределение финансовых средств на водоохранные мероприятия между водопользователями в пределах ограниченной суммы финансирования. Устанавливается также, насколько изменяется качество воды в водном объекте. Рассмотрена возможность практического применения предложенной методики.

КЛЮЧЕВЫЕ СЛОВА: финансирование водоохранных мероприятий; качество воды; водный объект; водопользователь; объекты транспортной инфраструктуры; индекс чистоты воды; концентрация загрязнений; индекс экологической эффективности; предельно допустимый сброс

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INTRODUCTION

Transport, like industry and energy, is a major water consumer and source of environmental pollution, including water resources [1].

In the XIX — beginning of the XX century, water supply facilities were crucial for the organization and successful operation of the transportation process under steam traction. In the subsequent period, with the transition of railway transport to other types of traction, water continues to be used for domestic, industrial purposes, large volumes of water are consumed when washing rolling stock, containers (including tanks of cisterns that carry various liquids), as well as at firefighting facilities of transport infrastructure. At the moment, issues related to drainage and treatment of wastewater (WW), rational use and protection of water resources are of paramount importance for rail transport facilities, as well as for other industrial sectors.

In order to preserve and improve water quality in water bodies at industrial and transport enterprises, including railway enterprises, water protection measures need to be implemented, which require constant and significant funding. In the Transport Strategy of the Russian Federation to 2030 with a forecast for the period up to 2035[1], Federal Law No. 416-FZ "On Water Supply and Sanitation"[2], other existing documents usually do not provide economic justification for strict regulatory requirements on the discharge of waste water into water bodies. As a result, practically all water users become hostages to the current situation, as there are insufficient financial resources to meet the required standards.

Relative investment in environmental protection (EP) in Russia is significantly lower than in some other countries (*see Table*).

From 1990s till present, the situation with regard to water protection measures in the Russian Federation has deteriorated (*Fig. 1*). From 1992 to 2020, according to the Russian Statistical Yearbook 2022 [1], indicators such as the relative investments in fixed capital aimed at protecting water resources, the commissioning of sewage treatment plants and the implementation of water recycling systems are decreasing.

[1] Transport Strategy of the Russian Federation until 2030 with a forecast for the period until 2035 (approved by the Decree of the Government of the Russian Federation dated 27.11.2021 No.3363-r).

[2] Federal Law No. 416-FZ dated 07.12.2011 on Water Supply and Sanitation. Moscow, ConsultantPlus, 78 p.

Table

Environmental protection costs [2]

Country	% of GDP	GDP, $ billion in 2017	EP costs, $ billion	Territory, thousand km²	Investment per unit area, thousand $/km²
Russia	0.9	3807	34.3	17 125	2.00
France	1.0	2983	29.8	552	54.0
Germany	0.7	4377	30.6	358	85.6
UK	0.7	3022	21.2	242	87.4
Japan	1.3	5194	67.5	378	179

Despite the lack of funding for water protection measures, the maximum permissible concentrations (MPC) of pollutants in wastewater, including from transport infrastructure, when discharged into wastewater disposal systems and water bodies in Russia are often set very high, sometimes more stringent than for drinking water (*Fig. 2*), which leads to unjustified investment costs.

RESULTS OF THE STUDY

At present, the Russian Federation has not yet established market relations in the field of nature and, in particular, water use. There are a number of difficulties in the implementation of these relations in our country, the main ones being:

- there is no legal basis for regulating such relationships;
- financing opportunities for water protection measures, as a rule, do not allow achieving the required values of maximum permissible discharges (MPD)

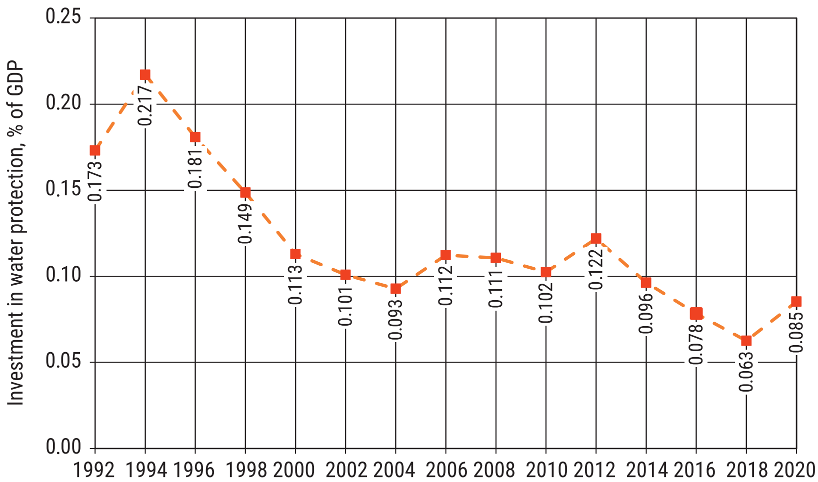

Fig. 1. Investment in water protection, % of GDP
Water protection measures in the Russian Federation in 1992–2020

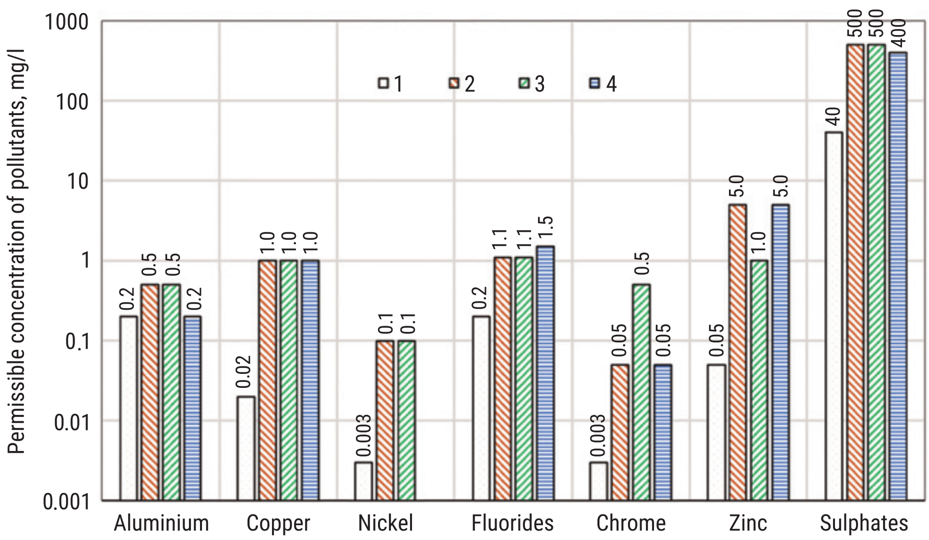

Fig. 2. Permissible concentrations of pollutants: *1* — in industrial wastewater in Saint Petersburg; *2* — in drinking water; *3* — in domestic and drinking water bodies; *4* — in drinking water according to the recommendations of the World Health Organisation (WHO)

of pollutants in the required time; this obliges either to significantly increase financing of environmental protection measures to the detriment of other economic activities, or to reduce requirements to the quality of waste water discharged into water bodies in accordance with our capabilities. Over the last decade, new less stringent requirements for permissible pollutant discharges have been established abroad in comparison with previously existing ones, taking into account real possibilities of financing. These actions made it possible to implement market mechanisms in environmental protection activities to the full extent;

- there is no substantiated methodology for determining permissible pollutant discharges into urban wastewater networks, depending on MPC of pollutants discharged into water bodies, which often leads to a paradoxical situation: in many cases, the requirements for wastewater discharged by water users into urban wastewater networks are stricter[3,4], than MPC of pollutants in water bodies or drinking water indicators (SanPiN[5] and WHO recommendations);
- there is no methodology for changing the quality of water in a water body depending on the amount of investment in water protection measures in the basin of the water body.

Let us consider the latter circumstance in more detail.

Suppose that for a group of water users of one water basin it is necessary to choose a rational way of financial allocation and at the same time to obtain the highest possible water quality of a water body, which under a certain background pollution depends on WW quality of water users [3].

Fig. 3 shows a graphical interpretation of the solution to the problem.

A general criterion for water quality of a water body can be the water purity index I_p [4], which for the i-th pollutant is determined by the formula

$$I_p = \sum_{j=1}^{n} \frac{\text{MPC}_j}{C_j}, \quad (1)$$

where MPC_j and C_j — respectively the maximum permissible concentration and the actual concentration of the j-th pollutant.

Water users aim to find the maximum function $I_p(I_i)$, where I_i —WW purity index of the i-th water user.

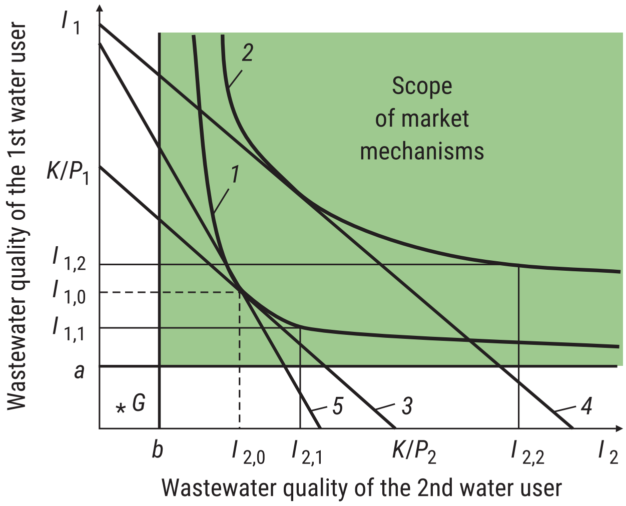

Fig. 3. Graphical interpretation of the solution to the water quality condition selection problem for two water users: *1* — function level curve $I_p = f(I_1, I_2) = \text{const}_1$; *2* — new function level curve $I_p = f(I_1, I_2) = \text{const}_2$ with increased funding opportunities; *3* — the old line of budgetary restraint $P_1 \cdot I_1 + P_2 \cdot I_2 = K$; *4* — a new line of budgetary constraint while maintaining the price ratio of I_1 and I_2; *5* — a new line of budgetary constraint when the price ratio changes I_1 and I_2

Since water users are often limited in funds, they can spend part of this money in order to invest it in improving WW quality of one water user, and another part in improving the WW quality of another water user, etc. Suppose also that P_i — the price of improving the "quality unit" of WW of the i-th water user.

In general terms, the challenge facing water users in a water basin can be formulated as follows

$$I_p(I_i) \to \max; \quad (2)$$

$$\Sigma(P_i \cdot I_i) \le K; \quad (3)$$

$$I_i \ge 0. \quad (4)$$

In order to visualise the condition of the problem, let us assume that the water quality of a water body needs to be selected for two water users. Let us denote WW quality of one water user I_1, that of the second one — I_2. P_1 should be paid for the improvement of the first water user's WW (i.e. P_1 — the price of a "quality improvement unit" of WW of the first water user, and for the improvement of the second water user's

[3] Bezpamyatnov G.P., Krotov Yu.A. Maximum permissible concentrations of chemical substances in the environment: handbook. Leningrad, Chemistry, 1985;528. (In Russ.).

[4] Guidelines for drinking water quality control. Volume 1. Recommendations. Geneva, World Health Organisation (WHO), 1986;126.

[5] SanPiN 2.1.3684-21. Sanitary and epidemiological requirements for the maintenance of urban and rural settlements, water bodies, drinking water and potable water supply, atmospheric air, soils, living quarters, operation of industrial and public buildings, organization and conduct of sanitary and anti-epidemic (preventive) measures. Moscow, 2021;66. (In Russ.).

WW, P_2 should be paid. In this case, the task can be expressed as follows

$$I_p(I_1, I_2) \to \max;$$
$$P_1 \cdot I_1 + P_2 \cdot I_2 \leq K;$$
$$I_1 \geq 0; \quad I_2 \geq 0.$$

Let's assume that $I_{1,0}$ and $I_{2,0}$ — is an optimal solution of problem (2)–(4), the constant a defines the minimum permissible level of WW of the first water user (MPD_1), which depends on MPC of pollutants in water of the water body; the constant *b* defines the minimum permissible level of WW of the second water user. The I_p functions in this case can be calculated as follows

$$I_{p1} = f_1(a, b, P_1, P_2, K); \quad (5)$$
$$I_{p2} = f_2(a, b, P_1, P_2, K). \quad (6)$$

The constants *a* and *b* set the lower limits for the quality of the WW of water users (MPD_1 and MPD_2).

Demand for WW quality of water users and, consequently, water bodies is functionally related to the prices for WW quality improvement of each water user and the financial possibilities of each water user.

Function level line $I_p = f(I_1, I_2)$ indicates all points I_1 and I_2, for which the following equation is fulfilled $I_p = f(I_1, I_2)$ = const (i.e. the value of the criterion is the same for these points). If we take another point, for example $I_p = f(I_{1,1}, I_{2,1})$, lying on this curve, the value of the criterion will not change, i.e. $I_p = f(I_{1,1}, I_{2,1}) = f(I_{1,0}, I_{2,0})$, However, it will cost more to ensure $I_{1,1}$, $I_{2,1}$ for water users.

A change in *K* value results in a parallel shift of the budget constraint line. A change in the price ratio changes the slope of the budget constraint line (see *Fig. 3*).

This problem has a solution only if $P_1 \cdot a + P_2 \cdot b \leq K$, i.e. in the first place, it is necessary to ensure WW quality at the minimum permissible level, and then to spend the remaining funds for additional water quality improvement. If the financial resources of natural resource users *K* exceed the minimum allowable value, the remaining part is divided according to the type of dependence (2): $I_p = f(I_1, I_2)$. If water users have only had enough to ensure that the quality of WW is at a minimum acceptable level, i.e. $P_1 \cdot a + P_2 \cdot b = K$, they have no choice but to choose this particular set. The cost ratios of ensuring quality of WW of the water users, which determine the slope of lines 4 and 5, have no influence on this choice.

The water quality choice area of a water body, which depends on the quality of WW of water users, can be divided into three zones (see *Fig. 3*):

- quality of WW of water users above the maximum permissible values MPD_i (lines *a* and *b*) — the scope of market mechanisms;
- quality of WW of water users is equal to the maximum permissible values (lines *a* and *b*) — lines of administrative regulation;
- quality of WW of water users cannot be ensured for one reason or another (e.g. financing conditions) — an area of uncertainty.

The peculiarity of the current state of water use in Russia is that the allocated amount of funds *K*, as a rule, is insufficient even to ensure the quality of discharged to water bodies at the minimum acceptable level, i.e. the necessary condition of the market mechanism according to the formula (3) is not met, there is no possibility to maneuver financial resources.

In order to meet the current MPC standards for pollutants in wastewater discharged into water bodies in our country, it is necessary to increase significantly funding for water protection measures.

It should be borne in mind that these costs are minimal and sufficient only to meet the regulatory requirements for the quality of waste water discharged into water bodies. For normal functioning of water protection relations under market economy conditions (providing some freedom of choice), they should be several times higher.

At present, Waste water quality of the majority of water users in the Russian Federation (and, accordingly, of water bodies) can be conditionally characterized by the position of point *G* in *Fig. 3*.

In this regard, the view of some experts that a system of penalties can be progressive in our conditions in the field of drainage and protection of water resources is untenable. It can be so only if it serves as an incentive to introduce new technologies, if the natural resource user has a choice: to improve production or pay a fine. At present, water users have no such alternative.

CONCLUSION

Relative financing of water protection measures in the Russian Federation is considerably lower than in foreign countries, and has been declining in our country over the past three decades.

The limits for concentrations of pollutants in WW when discharged into water bodies and water disposal systems in Russia without economic justification are often set very strict, sometimes more stringent than for drinking water, which leads to unjustified expenditure of investment costs.

The authors propose a methodology for determining the dependence of water quality of a water body on the actual financing of water protection measures.

Consideration is given to the practical application of the proposed methodology.

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