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IMPROVEMENT OF PERIODIC DISTRIBUTION OF WATER RESOURCES ROUTINE CONSIDERING THE ASSIMILATIVE CAPACITY OF A RECIPIENT RIVER

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Abstract
One of the topical environmental problems is the pollution of river waters due to the periodic dumping of pollutants with return water from the accumulators of polluted industrial or mine waters. This problem is urgent for many enterprises of the chemical industry of the world, and in particular Ukraine. The lack of an approved methodology for the development of regulations for the periodic dumping of return water from storage can lead to violations of regulatory requirements for the quality of surface water. The purpose of the study is to improve the regulation of the periodic drainage of return water from the sludge tank at PJSC Sumykhimprom in the Psel River, taking into account the seasonal absorption capacity of the recipient river, which is necessary to ensure regulatory requirements for the quality of surface water in the control section of the return water production. In order to achieve the goal, the following tasks were solved: the minimum multiplicity of dilution of return water required for the fulfillment of regulatory requirements was calculated; the typical hydrograph of the Psel River was constructed and analyzed; the maximum allowable return water costs were determined in the months of the year; the distribution return water discharge volume was calculated, while accounting for the assimilative capacity of the recipient river. An improved algorithm was used to calculate the regulations for the return water discharge from the accumulators of polluted industrial water of OJSC Sumykhimprom. It is determined that the minimum required multiplicity of dilution in the control section of issue № 2 of JSC «Sumykhimprom» is determined by the indicator of ammonium nitrogen and is 222.3. March and April were the most favorable for the discharge of return water, while the maximum allowable return water costs for these months were respectively 0.11 and 0.08 m^3/s.
Keywords: surface waters; typical hydrograph; reciprocal dilution; concentration of substances; Frolov-Rodziller method.

1. Problem statement and analysis of the recent researches and publications.

One of the most urgent environmental problems of today is the pollution of surface waters [1–3]. There are several reasons for the unsatisfactory state of water bodies as the seepage of pollutants through the soil [4, 5], and the discharge of pollutants with the return water of industrial enterprises [6].

The main industries use water in their technological processes. Consequently, the discharge of liquid industrial waste in surface water can lead to an increase in the concentration of chemicals in water [7, 8]. The ingress of contaminants with return water to water bodies may harm the aquatic environment [9–11] and human health [12].

Regulation of the processes of discharge of polluting substances with backwater is based on the Water Framework Directive (WFD), which aims to protect the aquatic environment and human health by reducing the discharge of pollutants into surface water bodies [13]. To achieve this, the concentration of priority substances in the return water should be lower than the values of environmental quality standards (EQS).

In cases when EQS compliance of the sewage is technically unfeasible, the EQS should be respected at a distance close to the discharge point. The zones near the discharge points, where the priority substances exceed the corresponding values of the EQS, are called mixing zones [13]. Any discharges of waste water will lead to changes in water quality and biological health when receiving water [6]. These changes can be virtually immaterial or they can be substantial. The degree and magnitude of these changes determine the mixing zone. Mixing zones are a responsible management tools for environmental components. According to EPA Victoria for river waters, the mixing zone should be calculated in low river flow conditions, taking into account seasonal and climatic variability. Low river flow conditions should be determined on the basis of long-term data under different climatic conditions (for example, with a view to drought) [15].

In Ukraine, in order to regulate the processes of discharge of return water into surface water objects, the norms, similar to EQS, are the maximum allowable concentrations (MAC) substances. Except for the water objects of drinking water, there are 2 types of MAC: for water objects of fishing purposes (fish-farming MACs) and for water objects of communal and domestic use (communal-household MDP). According to the Regulations for the Protection of Surface Waters [18], the requirements for the discharge of return water depend on the location of the return water. If the return water is located within the boundaries of the settlement, communal household appliances must comply directly with the return water. If the return water discharge is located outside of a settlement, the assessment of the implementation of regulatory requirements takes into account the dilution of reverse water by surface waters. In this case, the fishery management MACs must be observed in the control area of the return water release.

For rivers, the control bridge is assigned at a distance no further than 500 m from the release, below the current.

The discharge of return water into the river can be carried out both through continuous issues, and periodically (at certain periods of the year). Periodic dumping of return water is carried out from technological reservoirs: drives of polluted industrial or mine-career waters, fishing ponds, reservoirs-coolers of power stations. With continuous dumping of return water, compliance with regulatory requirements is ensured by developing a special document «Draft norms for maximum allowable discharges (MAC) of substances with return water». When developing the MAC regulatory requirements are achieved through compliance with the return limits of the calculated allowable concentrations of substances at a pre-approved maximum return flow rate. There is an approved methodology for calculating the MAC regulations for substances with return water during their permanent discharging [19]. In the case of periodic dumping of return water, compliance with regulatory requirements in accordance with the Water Code of Ukraine [20] is ensured through the development of individual regulations for the periodic discharge of return water. When developing individual regulations, regulatory requirements are achieved through compliance with the maximum permissible cost of return water with pre-known concentrations of pollutants in the reverse waters. Calculation of the maximum allowable flow of return water during their periodic dumping is carried out in an arbitrary form; there is no approved methodology for calculating the regulations for the periodic discharge of return water. This can lead to a breach of regulatory requirements, first of all, in shallow years. Therefore, there is a need to improve the methodology for calculating the regulations for the periodic dumping of return water.

2. Statement of the problem and its solution.

The problem of improving the regulation of periodic dumping of reverse water into the river is relevant for many industrial enterprises in Ukraine. In particular, this problem is relevant for the discharge of return water by the company «Sumykhimprom» in the Psel River [14, 23–24].

The aim of the study is to improve the regulations for the return of water from the Sumykhimprom Company in the Psel River to provide regulatory requirements for the quality of surface water in the control section of the return water production. To achieve this goal, the following tasks must be solved:

– improve the method of calculating allowable return water costs when discharged from the storage tank for different river flow costs;

– develop an algorithm for calculating the regulations for the discharge of return water from the reservoir of contaminated industrial waters OJSC Sumykhimprom;

– test the advanced method of calculating the regulation of periodic dumping of return water from storage units on the example of real data on the volume of return water in the storage of OJSC Sumykhimprom and the conditions for their dumping in the Psel River.

2.1. Materials and methods.

Description of study area and of the sewage disposal scheme. The Psel River runs on the territory of Russia (the Belgorod and Kursk regions) and Ukraine (within the Sumy and Poltava regions). This left tributary of the Dnieper (the Black Sea basin). The length of the river is 717 km; the area of the basin is 22800 km^2. The area of the Psel catchment area in Ukraine is 16270 km^2 [17].

Sewage of return water of PJSC «Sumykhimprom» is carried out in the Psel River in two issues. By the issue № 1 in the Psel River, reverse mixed industrial, household, rain and snow waste water are diverted. Issue № 1 is located on the left bank of the Psel River within the settlement (figure 1). Output № 2 provides sewage treatment of industrial waste water purified from neutralization plant and littered with sludge (physico-chemical treatment). Output № 2 is a coastal free-flow, located on the left bank of the Psel River outside of the settlement (below the output № 1) (figure 2).

Description of the characteristic and composition of sewage in the output. The composition of sewage in the output is given in table 1–4. Since the output № 1 is located within the city of Sumy, the data on concentrations of substances of the specified issue contain data on communal and municipal MAC substances, but for the output № 2, located outside the of the city, the data on fishery MACs.

Figure 1 – Map-scheme of the return water release of JSC «Sumykhimprom»

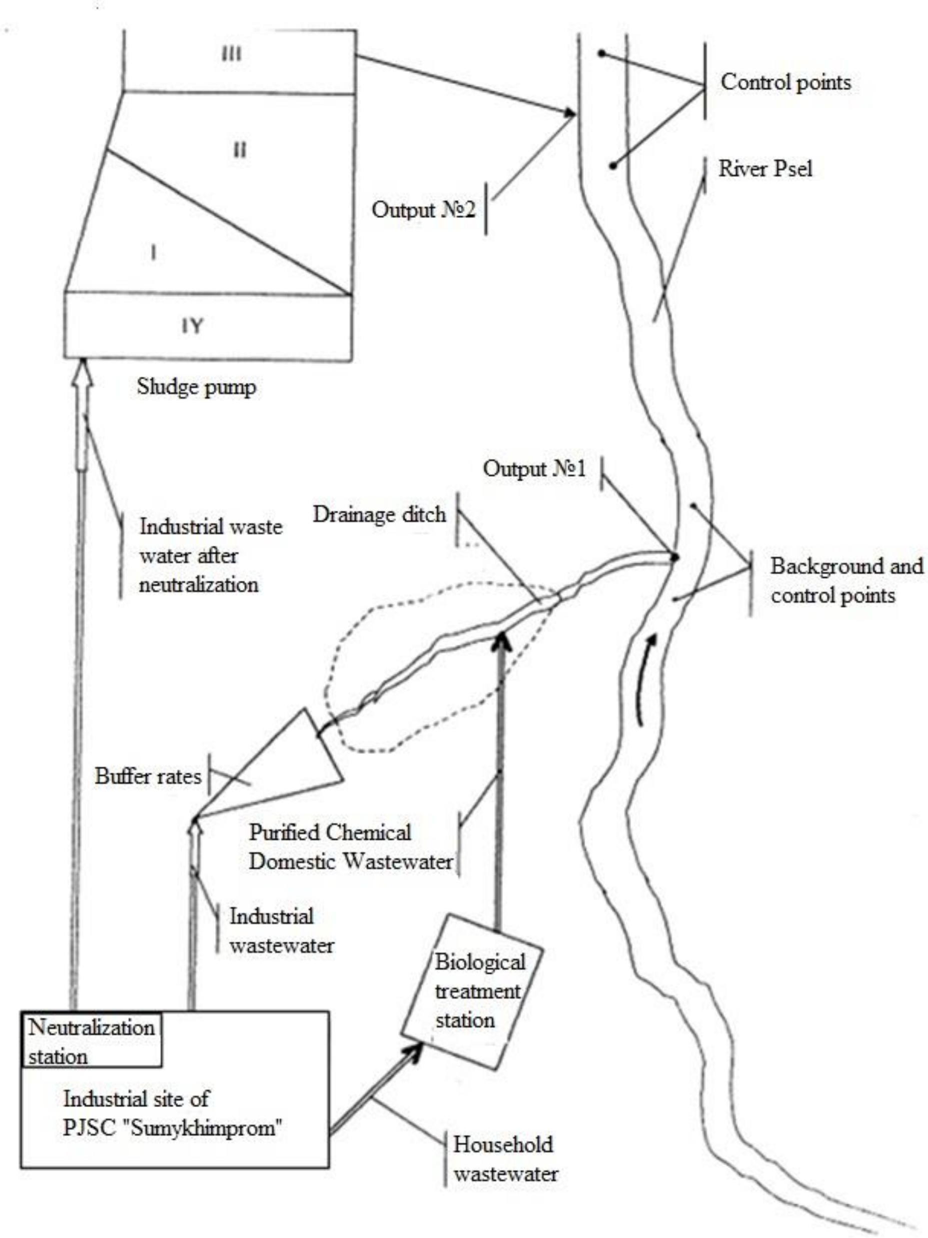

Figure 2 – Schematic plan of the 1st and 2nd wastewater discharge of PJSC «Sumykhimprom»

Table 1 – Composition of sewage of issue № 1 after clearing and MAC substances (mg/dm^3)

Parameter	Iron	Ammonia nitrogen	Nitrates	Nitrites	Fluorides	Chlorides	Suspended substances	Sulfates
The average	0.27	0.63	4.50	0.09	1.69	134.77	7.37	524.76
Communal and municipal MAC	0.3	2	45	3.3	0.7	350	Background +0.75	500

Table 2 – Composition of sewage of issue № 1 after clearing and MAC substances (mg/dm^3)

Parameter	Mineralization	Phosphates	Arsenic	Biochemical Oxygen Demand 5	Chemical Oxygen Consumption	Cadmium	Manganese	Zinc
The average	1234.77	9.05	0.01	4.84	28.18	0.0005	0.07	0.02
Communal and municipal MAC	1000	3.5	0.05	4.5	50	0.001	0.1	1.0

Table 3 – Actual concentrations of pollutants in sewage waters of issue № 2 of Sumykhimprom before discharges and MAC substances (mg/dm^3)

Parameter	Iron	Ammonia nitrogen.	Nitrates	Nitrites	Fluorides	Chlorides	Suspended substances	Sulfates
The average	0.02	22.53	11.34	5.35	1.17	147.13	3.54	2147.14
MPC fishery	0.1	1	40	0.08	Background +0.05	300	Background +0.75	100

Table 4 – Actual concentrations of pollutants in sewage waters of issue № 2 of Sumykhimprom before discharges and MAC substances (mg/dm^3)

Parameter	Mineralization	Phosphates	Cadmium	Manganese	Nickel
The average	3040.75	0.15	0.0003	0.04	0.02
MPC fishery	–	2.15	0.005	0.01	0.01

Background concentrations of substances in the Psel River are given in table 5.

Table 5 – Background quality of water in the Psel River is higher than the runoff discharge water issue № 1

№	Indicator of water quality	Background concentration, mg/dm^3
1	Iron is common	0.16
2	Ammonia nitrogen	0.97
3	Nitrates	4.34
4	Nitrites	0.4
5	Fluorides	0.59
6	Chlorides	23.71
7	Suspended substances	15.25
8	Sulfates	88.58
9	Mineralization	509.17
10	Phosphates	1.35
11	Arsenic	0.00
12	Biochemical Oxygen Demand 5	4.6
13	Chemical Oxygen Consumption	24.36
14	Cadmium	0.0009
15	Manganese	0.07
16	Zinc	0.01
17	Nickel	0.00
18	Petroleum products	0.00

As can be seen from the tables 1–2, concentrations in the return waters of the output № 1 of such substances as phosphates, fluorides, BOD5 and sulfates exceed the communal – household MPC, which indicates the need for additional wastewater treatment.

The discharge of return water from a slurry storage tank (output № 2) is carried out during a flood period of no more than 28 days per year. Hydrological characteristics of the Psel River in the area of issues are as follows:

– the average width – 31 m;

– the average depth – 2 – 3.2 m;

– the average flow rate of water in the flood is usually 25.7 m^3/s;

– the average volume of spring flood is usually 470 million m^3;

– the average flood passing – 60 days;

– the average flood date – March 12;

– the average flooding date – May 10.

The distribution of river runoff for months of years of varying water content is given in [21] in table 6.

Table 6 – Distribution of river runoff (%) by months of years of different water content (1 – water rich year, 2 – medium, 3 – shallow, 4 – very shallow)

Water content	Months of the year											
	3	4	5	6	7	8	9	10	11	12	1	2
1	48	11.1	3.2	3.2	3.1	2.1	1.5	2.2	2.6	4.1	3.1	15.8
2	40.9	16.3	6.6	4.2	2.6	2.1	2.6	3.2	4.3	6.9	4.5	5.8
3	33.6	19.8	9.4	4.2	2.8	2.2	2.8	3.8	5.1	7.3	4.8	4.2
4	33.9	19.1	8.2	5.1	3.6	3.1	3.9	4.1	4.3	6.8	3.8	4.1

A procedure is proposed for the development of the regulations for the periodic discharge of return water, which provides for the following stages of calculations:

1. Calculation of the minimum reciprocal dilution of return water n* required to achieve regulatory requirements.

2. Construction of the typical hydrograph of the Psel River for a year of low water content.

3. Calculation of the maximum allowable costs of return water in the months of the year, taking into account the cost of river water in accordance with the construction of a hydrograph.

4. Calculation of the distribution of volumes of discharge of return water by months of the year.

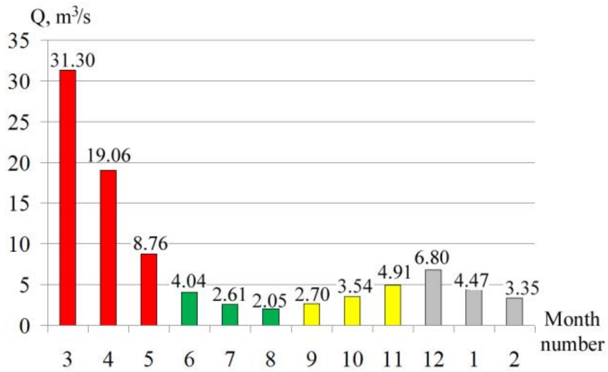

Figure 3 – The typical hydrograph of the Psel River for the year of low water content (different colors indicate the flow of river water in different seasons of the year)

2.2. Results and discussion.

2.2.1. Construction and analysis of the typical hydrograph of the Psel River. Based on Table 6 and data on average river flow costs in the Psel River, a typical hydrograph of the Psel River in the Sumy Oblast for a year of low water was constructed into the flood (figure 3).

As is evident from the hydrograph, the most favorable months for the return of water to March (Q = 31.30 m^3/s) and April (Q = 19.06 m^3/s).

A year of low water content corresponds to 75 % of the cost of river water consumption, and a year of very low water content – 95 % of supply.

2.2.2. Calculation of the minimum reciprocal dilution of return water required to meet regulatory requirements. Minimum reciprocal dilution is required, which ensures the fulfillment of regulatory requirements in the control section for all substances n*, is calculated by the formula

$$n^* = \max_{i=1}^{s}(n_i), \tag{1}$$

where i – the number of normalized substance, the concentration of which is in the reverse water C_i^{RW} exceeds the permissible norm of this substance C_i^{MAC}; s – the amount of such substances; n_i – minimum reciprocal dilution is required, which ensures that the maximum permissible values for this substance are not exceeded.

If the concentration of i-th substance in the background, that is, background concentration C_i^f , less than the standard of this substance C_i^{MAC}, the value n_i is calculated by the formula

$$n_i = \frac{C_i^{RW} - C_i^f}{C_i^{MAC} - C_i^f}. \tag{2}$$

If the background concentration of the i-th substance exceeds the norm, in the control section, with any multiplicity of dilution of reverse water, the achievement of regulatory requirements is excluded. In this case, taking into account the experience of valuation of reverse water drainage in EU countries [22], the required multiplicity of dilution for this substance should be calculated based on the condition that the background concentration of the substance is not exceeded in the control background of more than a certain percentage of the background concentration.

As can be seen from the tables 5 to 6, the exceedance of permissible standards in reverse water of output № 2 was observed only for the following indicators: ammonium nitrogen, nitrites, fluorides, sulfates, manganese and nickel. For nitrite and nitrogen, ammonium background concentrations exceed the permissible standard, therefore the maximum permissible concentrations in the control line were assumed to be equal to 10 % higher than the background concentrations.

The rest of the indicators of concentration in the return waters did not exceed the fishing regulations; therefore, for the implementation of regulatory requirements in the control section according to these indicators does not require dilution of return water. The results of calculating the required minimum multiplicity of dilution of return water in the control section for indicators whose concentrations exceed the allowable values are given in the table 7.

As is seen from the calculation results, the required multiplicity of dilution is determined by the indicator ammonium nitrogen and is 222.3.

Table 7 – Output data and results of calculating the required minimum dilution multiplicity

Pollutants	Actual concentration	Background concentration	MPC fishery	The required dilution ratio	Maximum permissible concentration at the control point
Ammonia nitrogen	22.53	0.97	0.39	222.3	1.07
Nitrites	5.35	0.4	0.08	123.8	0.44
Fluorides	1.17	0.59	0.64	11.6	
Sulfates	2147.14	88.58	100	180.3	
Mineralization	3040.75	509.17	1000	5.2	
Nickel	0.02	0	0.01	2	

2.2.3. Determination of the maximum return water loss, for which the regulatory requirements are not exceeded, by months of the year. Since the reciprocal dilution of the return water is a monotonically decomposable function of the flow of return water n(q), the mathematical formulation of the problem of determining the maximum permissible flow of return water q_{max}, in which, in the control section, the required multiplicity of dilution of the reciprocal waters n* is reduced to the solution of the equation

$$n(q_{max}) = n^*. \tag{3}$$

The output of the return water is considered to be free-flow, so the initial reciprocal dilution is assumed to be equal to 1, and the general multiplicity of dilution is equal to the multiplicity of the main dilution. The specific form of the function n(q) depends on the type of water object – the receiver of return water (river or water), as well as many parameters. For rivers, the most important parameter is the flow of river water. If discharging sewage into small rivers, when sewage flow q significantly exceeds the cost of river waters Q, the calculation of the multiplicity of the main dilution can be performed in the approximation to complete mixing. The multiplicity of the main dilution in this approximation is determined by the formula

$$n(q) = \frac{q + Q}{q}. \tag{4}$$

From formulas (3) and (4) we find an expression for the value q_{max}

$$q_{max} = \frac{Q}{n^* - 1}. \tag{5}$$

To calculate the multiplicity of dilution when discharged sewage in the middle and large rivers, the method of Frolov-Rodsiller is most often used. According to this method, to calculate the multiplicity of dilution at a certain distance L from the discharge, where not the entire river flow is involved in mixing with sewage, but only a certain part thereof, use the formula similar to (4)

$$n_0 = \frac{q + \gamma Q}{q}, \tag{6}$$

where γ – mixing factor, which shows which part of the flow of river water is involved in mixing $(\gamma \le 1)$.

In this case, the equation (3) is solved by numerical or graphical methods. Since the width of the Psel River is relatively small for calculations using the Frolov–Rodsiller method, a one-dimensional model was used. At the same time, the coefficient γ was calculated as follows

$$\gamma = \frac{1 - \exp\cdot(-\alpha \cdot \sqrt[3]{L})}{1 + \frac{Q}{q}\cdot \exp\cdot(-\alpha \cdot \sqrt[3]{L})}, \quad (7)$$

where α – the coefficient for which there is the following approximate dependence on the coefficient of turbulent diffusion, the riveting of the river and the position of the discharge

$$\alpha = \xi \cdot \varphi^3 \cdot \sqrt{D/q}, \quad (8)$$

where D – coefficient of turbulent diffusion; ξ – coefficient taking into account the location of the issue (ξ =1 – for the coastal release and ξ =1.5 – for the riverbed release); φ – river riveting coefficient:

$$\varphi = \frac{L}{L_{st}},$$

of waste water to the control area; L_{st} – distance from the output to the control area in a straight line.

To calculate the multiplicity of the total dilution n, turbulent diffusion coefficients have been calculated. In the estimation of the coefficients of turbulent diffusion in rivers and reservoirs (due to the lack of significant vertical stratification of waters), the coefficients of horizontal and vertical turbulent diffusion can be considered equal to each other: $D_v = D_h$ =D. In the absence of a complete freezing, the value D for small distances from the output (up to 1000 m) is determined by the formula

$$D = \frac{g \cdot u \cdot R}{37 \cdot n_r \cdot C_r^2}, \quad (9)$$

where $g = 9.81$ m/s^2 – free fall acceleration; R – hydraulic flow radius, m ($R \approx H$, where H – average depth of the river, m); n_r – the coefficient of roughness of the bed of the river, which is determined according to the table by M. F. Sribny; C_r – coefficient of Shezy, $\frac{\sqrt{m}}{s}$, if $R \le 5$ m is determined by the formula of N. N. Pavlovsky (10)

$$C_r = \frac{1}{n_r} \cdot R^y, \quad (10)$$

where

$$y = 2.5 \cdot \sqrt{n_r} - 0.13 - 0.75 \cdot \sqrt{R} \cdot (\sqrt{n_r} - 0.1). \quad (11)$$

Output data for the calculation and the main intermediate results of calculating the multiplicity of dilution are presented in table 8.

The equation (3) was solved by the graphical method and in the Excel system using the «Find Search» add-in.

The graphic solution for the 3 months of the year, corresponding to the highest cost of river water, is shown in figure 6.

As a result of the solution of equation (3) with Excel, the following values were obtained for the maximum allowable costs of return water:

– for March $q^3_{max} = 0.11$ m^3/s;

– for April $q^4_{max} = 0.08$ m^3/s;

– for May $q^5_{max} = 0.04$ m^3/s.

Table 8 – Output data and main intermediate results of calculating the multiplicity of dilution

The speed of the river, u	0.6	Hydraulic radius of flow, R	2
Roughness coefficient of the channel, n_r	0.029	Mixing factor, y	0.221177
River curvature ratio, φ	1.5	Shezie's coefficient, C_r	40.196
Free fall acceleration, g	9.81	Turbulent diffusion coefficient, D	0.00679

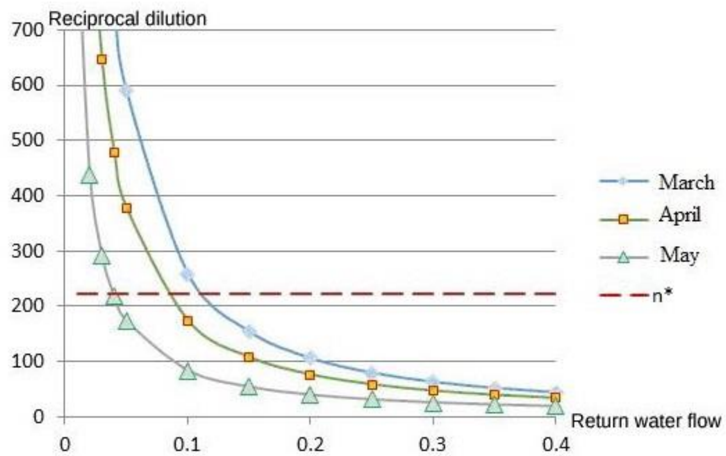

Figure 6 – Determination of maximum allowable return water flow graphic method

2.2.4. Calculation of the distribution of volumes of discharge of return water by months of the year. The proposed algorithm for calculating the distribution of volumes of return water discharges by months of the year is based on the principle of maximizing the use of the assimilative capacity of the river – the receiver of return water. Assuming background concentrations of substances constant during the year, the assimilation capacity of the river is proportional to the cost of river water. Therefore, when calculating the distribution of volumes of discharge of return water in the months of the year, priority should be given to the month of the year when there are higher river costs.

In this way, an algorithm for calculating the rules for periodic dumping of return water is proposed, which involves performing the following calculation steps.

Step 1. Calculate the minimum reciprocal dilution in the control n*, required for environmental requirements (non-exceeding the fishery regulations in the control site). The calculation is performed according to the formula (2) or the condition of not exceeding in the control background of the substance concentration more than 10 % of the background concentration.

Step 2. Based on the typical hydrograph of the river-receiver of return water, constructed based on the water content of the year, the average monthly cost of the Q river for the month is used, which is the best in terms of diluting the return water. The best month is chosen for the maximum cost of the river, as it provides the highest multiplicity of dilution.

Step 3. For the selected month in step 2, the maximum allowable return flow q_{max} is calculated, which achieves the required minimum multiplicity of dilution of the return water n*. Value q_{max} is determined by solving the equation (3).

Step 4. Calculates the time t (days) required to drain the return water volume V_t remaining in the drive before the beginning of the month. The calculation is performed according to the formula

$$t = \frac{V_t}{86400 \cdot q_{max}}. \qquad (12)$$

If the condition is fulfilled

$$t \le t_m,$$

where t_m – number of days in the selected month, calculation is over; otherwise, the return to step 2 is performed.

Results of the calculation of the regulations for the discharge of return water from the sludge pump OJSC «Sumykhimprom» for a shallow water year according to the proposed algorithm for the volume of return water in the sludge at the beginning of the year equal to V_0 = 685.7 thousand m^3 is shown in table 9.

Table 9 – Settlement regulations for return water discharge from Issue № 2 of OJSC Sumykhimprom for a shallow water year

Drainage stages	Volume of return water in the drive before the start of the stage, thousand m^3	Period (month of year)	Duration of the stage, the day	Return water costs, m^3/s
Stage 1	685.7	March	31	0.11
Stage 2	306.85	April	30	0.08

In case if the initial volume of return water is exceeded, an ecologically safe drainage system requires the 3rd stage of discharge.

Thus, based on the method of developing the regulation of periodic discharge of return water proposed in section 2, there were identified 2 stages of discharge of return water from the reservoir of polluted industrial water of OJSC Sumykhimprom, calculated maximum allowable return water costs and the duration of discharge of return water at each of the stages. The developed regulation ensures compliance with the regulatory requirements for the quality of surface water in the control area № 2.

Conclusion and recommendations.

The minimum required multiplicity of dilution in the checkpoint of the output № 2 of OJSC «Sumykhimprom» is determined by the indicator of ammonium nitrogen and is 222.3.

Based on the analysis of the typical hydrograph of the Psel River in the Sumy region, using the one-dimensional model of the Frolov-Rodziller method, the maximum allowable return water consumption in the months of the year of low water was calculated, at which the required multiplicity of dilution is achieved. The most favorable for discharging backwater is the months of March and April. The maximum allowable return water costs for these months are respectively 0.11 m^3/s and 0.08 m^3/s.

The improved method for calculating the optimal regulation of periodic dumping of return water from the storage facility of OJSC «Sumykhimprom» allows for the removal of the total volume of return water without violating regulatory requirements.

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Conflicts of Interest.

None of the authors have any potential conflicts of interest associated with this present study.

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ВДОСКОНАЛЕННЯ РЕГЛАМЕНТУ ПЕРІОДИЧНОГО СКИДАННЯ ЗВОРОТНИХ ВОД З УРАХУВАННЯМ АСИМІЛЯЦІЙНОЇ ЗДАТНОСТІ РІЧКИ-ПРИЙМАЧА

Однією з актуальних екологічних проблем є забруднення річкових вод внаслідок періодичного скидання забруднюючих речовин із зворотними водами з накопичувачів забруднених промислових або шахтно-кар'єрних вод. Зазначена проблема актуальна для багатьох промислових підприємств світу, й, зокрема, для України. Відсутність затвердженої методики розроблення регламентів періодичного скидання зворотних вод з накопичувачів, може привести до порушення нормативних вимог до якості поверхневих вод. Метою дослідження є вдосконалення регламенту періодичного відведення зворотних вод з шламонакопичувача ПАТ «Сумихімпром» у р. Псел з урахуванням сезонної асиміляційної здатності річки-приймача, що необхідно для забезпечення нормативних вимог до якості поверхневих вод в контрольному створі випуску зворотних вод. Для досягнення мети були вирішені наступні задачі: розрахована мінімальна кратність розбавлення зворотних вод, яка є необхідною для виконання нормативних вимог; побудовано та проаналізовано типовий гідрограф річки Псел; визначені максимальні допустимі витрати зворотних вод по місяцях року; розраховано розподіл обсягів скидання зворотних вод з урахуванням асиміляційної здатності річки-приймача зворотних вод. Удосконалений алгоритм застосовано для розрахунку регламенту скидання зворотних вод з накопичувачів забруднених вод підприємства ВАТ «Сумихімпром». Визначено, що мінімальна необхідна кратність розбавлення в контрольному створі випуску № 2 ВАТ «Сумихімпром» визначається за показником азот амонійний і становить 222,3. Найбільш сприятливими для скидання зворотних вод виявилися березень та квітень, а максимальні допустимі витрати зворотних вод для цих місяців становлять відповідно 0,11 і 0,08 м³/с.

Ключові слова: поверхневі води; концентрація забруднювачів; типовий гідрограф; кратність розбавлення; метод Фролова-Родзіллера.

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УСОВЕРШЕНСТВОВАНИЕ РЕГЛАМЕНТА ПЕРИОДИЧЕСКОГО СБРОСА СТОЧНЫХ ВОД С УЧЕТОМ АССИМИЛЯЦИОННОЙ СПОСОБНОСТИ РЕКИ-ПРИЕМНИКА

Одной из актуальных экологических проблем является загрязнение речных вод вследствие периодического сброса загрязняющих веществ с обратными водами из накопителей загрязненных промышленных или шахтно-карьерных вод. Указанная проблема актуальна для многих промышленных предприятий мира, и, в частности, для Украины. Отсутствие утвержденной методики разработки регламентов периодического сброса сточных вод из накопителей, может привести к нарушению нормативных требований к качеству поверхностных вод. Целью исследования является совершенствование регламента периодического отвода сточных вод из шламонакопителя ПАО «Сумыхимпром» в р. Псел с учетом сезонной ассимиляционной способности реки-приемника, что необходимо для обеспечения нормативных требований к качеству поверхностных вод в контрольном створе выпуска сточных вод. Для достижения цели были решены следующие задачи: рассчитана минимальная кратность разбавления сточных вод, необходимая для выполнения нормативных требований; построен и проанализирован типовой гидрограф реки Псел; определены максимально допустимые расходы сточных вод по месяцам года; рассчитано распределение объемов сброса сточных вод с учетом ассимиляционной способности реки-приемника сточных вод. Усовершенствованный алгоритм применен для расчета регламента сброса сточных вод из накопителей загрязненных вод предприятия ОАО «Сумыхимпром». Определено, что минимальная необходимая кратность разбавления в контрольном створе выпуска № 2 ОАО «Сумыхимпром» определяется по показателю азот аммонийный и составляет 222,3. Наиболее благоприятными для сброса сточных вод оказались март и апрель, а максимальные допустимые расходы сточных вод для этих месяцев составляют соответственно 0,11 и 0,08 м^3/с.

Ключевые слова: поверхностные воды; концентрация загрязнителей; типичный гидрограф; кратность разбавления; метод Фролова-Родзиллера.