Calculation of pollution of water bodies by wastewater of the Moscow region enterprise

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\textbf{Abstract.} In this paper, the author studies and calculates pollution of water bodies by wastewater of the Moscow region enterprise. The author reveals the general principles of determining the maximum discharge of pollutants as established standards for the water bodies quality, as well as the permissible and actual concentration, maximum permissible discharge, and total wastewater flow rate.

\section*{1. Introduction}
The issue of pollution of water bodies is very relevant for the Moscow region. The number of polluted water bodies in the study area is increasing every year. Despite the fact that there are standards for the maximum allowable discharge, some enterprises do not comply with them. It is necessary to control and monitor water bodies where the maximum permissible concentrations of pollutants are exceeded. Note that the Moscow region is a territory with a large number of depressive urban spaces. We calculated the pollution of a water body from an enterprise in the Moscow region. When calculating, we used sanitary rules and norms for the protection of surface waters from pollution and regulatory data on the maximum permissible levels of pollution of harmful environmental substances. Also, for calculations, we needed a list of maximum permissible concentrations and approximately safe levels of exposure to harmful substances for the water of fishery reservoirs and an annual report of surface water quality and the effectiveness of water protection measures on the territory of Roshydromet. At the end of the article, we provided an action plan to achieve the maximum allowable discharge into water bodies.

\section*{2. Materials and methods}
The leading foreign and domestic scientists (S.S. Rodionov, G.A. Larina, V.A. Khabarov, S.N. Volkov, V.V. Vreshinin, L.I. Egorenkov, and others.) give great attention to the issues of rational use of natural resources, regulation of the quality of the environment and the improvement of ways and methods in their works.
3. Results and Discussion
The calculation of the maximum permissible discharge has been performed particularly for the Moscow region enterprise. At the same time, the author has examined the enterprise territory and the territories into which the enterprise discharges its wastewater. For these purposes, the author has also studied archival materials of hydrological, as well as engineering and geological surveys.

The established standards of the maximum permissible discharge of pollutants are used to plan certain activities on clearing wastewater and calculating the payment amount to an environmental fund. The general principle for determining the maximum permissible discharge volume for any substances is the MPD indicator, which guarantees achievement of certain established standards and preservation of the water bodies quality level [1-5]. At the same time, stormwater is discharged from the enterprise territory directly onto the terrain. The maximum permissible discharge is calculated subject to strict consideration of the current quality standards applicable to fishery water bodies of the second category.

The calculations consider the main indicators forming the basis of the maximum permissible discharge from the enterprise territory.
1. Stormwater;
2. Wastewater category – stormwater;
3. The established wastewater flow rate required to determine the MPD – 4.39 m³/h;
4. The following wastewater indicators have been used:
   - The actual concentration of suspended particulate matter is 200.0 g/cm³, the actual discharge reaches 808 g/m³, and the permissible concentration representing the established MPD is 47.19 g/h;
   - The actual concentration of petrochemicals is 1.5 g/m³, with the actual discharge of 6.58 g/h;
   - The actual concentration of total iron reaches 1.5 g/m³, with the acceptable concentration of 0.1 g/m³.

There are no floating matters in this enterprise’s wastewater, in the 20 cm thick layer there is no color, there is no smell or taste, with the wastewater temperature not exceeding the monthly average. Its alkalinity index is 7.5. The quantity of coliform bacterium (the coli-index) does not exceed 10,000 per liter of liquid, and the dissolved oxygen quantity is no less than 4 mg/l up to the noon. There are no toxic substances in this enterprise’s wastewater.

The permissible discharge of substances found in wastewater is as follows:
1. Wastewater – 4.39 g/m³;
2. Suspended substances – 145 g/m³;
3. Concentration of petrochemicals – 1.1 g/m³;
4. Total iron – 1.2 g/m³.

The legal basis for the established limits and control of the maximum permissible discharge of get into water bodies with wastewater is regulated by the following legal acts, GOSTs and rules:
   - GOST 17.1.01 – 77 “Nature protection. Hydrosphere. Utilization of water and water protection. Basic terms and definitions.”
   - The list of maximum permissible concentrations and approximate safe levels of exposure to harmful substances for the water of fishery water bodies. – M., Medinor.
   - Sanitary rules and standards for preservation of surface waters against pollution. SanPiN 4630-88.
   - Regulatory information on the maximum permissible levels of the environment pollution with harmful substances: Reference material. – St. Petersburg.
   - Yearbook of surface water quality and efficiency of activities on water protection on the territory of the Moscow State Research Center of Roshydromet.
To determine the maximum permissible discharge amount, it is necessary to calculate the permissible amount of substances discharged into a water body during economic activity, provided that the water composition remains the same as was formed by the natural factors. The MPD amount is the basis for monitoring compliance with the established regimes of wastewater discharge into water bodies.

When determining the surface water quality standards, the following should be considered: the general requirements for the properties and composition of such waters, the list of MPC (maximum permissible concentrations), as well as approximate safe levels of pollutants for water bodies. It is necessary that the MPD comply with the purification levels in case the typical water protection technology for wastewater is applied.

Be noted that since the enterprise receives water from the general water supply system, the consumed water volume corresponds to the readings of the water meter installed in the administrative building. The estimated consumed water volume of the enterprise is 3.68 m$^3$ per day. Furthermore, it is drinking quality water that is used at all the main facilities of this enterprise. Besides, the shape, type, heights, and slopes of the terrain make it possible to outline the direction of surface stormwater flow. In addition, it must be kept in mind that stormwater flowing from the enterprise territory do not reach the terrain in full, since part of it is absorbed into the ground.

To determine the maximum permissible discharge, it is necessary to consider requirements established for the composition and properties of water in water bodies. The MPD indicator is the multiplication of the surface wastewater volume coming from the enterprise territory and the permissible concentration of harmful substances contained in the wastewater discharged by the enterprise:

$$MPD = C_p \times Q_{\text{water}}, \text{ g/h},$$

(1)

Where $C_p$ is the permissible concentration of a substance contained in the wastewater discharged by the enterprise;

$Q_{\text{water}}$ – is the stormwater flow from the enterprise territory, m$^3$/h.

A profile of the wastewater discharged to the terrain from the enterprise territory is recommended by the Moscow Regional Environmental Committee (table 1).

| Substance       | Limiting factor   | MPC in a fishery water body, mg/l | Actual concentration, mg/l |
|-----------------|-------------------|-----------------------------------|----------------------------|
| Suspended       | General sanitary  | 10.75                             | 200                        |
| Petrochemicals  | Fishery           | 0.05                              | 1.5                        |
| Total iron      | Toxicological     | 0.1                               | 1.5                        |

Table 1. Wastewater profile.

Stormwater flow from the enterprise territory is presupposed as the wastewater volume from 1 hectare, which results from extreme intensive rain lasting 20 minutes ($Q_{20}$). To determine the wastewater volume, $Q_{20}$ is multiplied by the wastewater formation area (F):

$$Q_{\text{water}} = Q_{20} \times F.$$  

(2)

Since the extreme intensive rain lasting 20 minutes results in 1.84 m$^3$ of precipitation, for the Moscow region this indicator is 1,362 l/s per 1 ha.

$$Q_{20} = 15.84 \text{ m}^3/\text{h per 1 ha}.$$  

(3)

Since in the Moscow region it precipitates for about 150 days per year, the volume of the wastewater dirtiest part per year ($V$) is the multiplication of $Q_{\text{water}}$ by 150 and amounts to:

$$V = 2.376 \text{ m}^3/\text{ha x F}.$$  

(4)
For each waterflow, the formation area is the sum of the multiplication of the objects with different types of surfaces and certain stormwater flow coefficients:

\[ F_i = S_i \times W_i, \]  

(5)

\[ F = zF_i = S \times W, \]

where \( i \) – is the object number;
\( n \) – the quantity of objects with different types of surfaces;
\( S_i \) – the area of object No. \( i \);
\( W \) – stormwater flow coefficient;
\( F_i \) – the waterflow formation area for object No. \( i \).

The names of these objects, as well as the surface types (\( S_i \), \( F_i \)) are provided in Table 2. The \( W \) values are taken from the Designer’s Handbook [5]. Calculations are given for the most polluted part of wastewater formed by a 20-minute-long rain.

For each group of substances that have equal limiting harmful index (LHI), the sum of each substance concentration should not exceed one; therefore, the sum of each substance concentration is correlated with the corresponding maximum permissible concentration (MPC).

### Table 2. Waterflow formation area.

| Object name, LHI | \( W \) | \( S_i \), ha | \( F_i \), ha |
|------------------|--------|-------------|-------------|
| Main and auxiliary roofs and buildings | 0.95 | 0.288 | 0.274 |
| Hard surfaces | 0.95 | 0.03 | 0.003 |
| - | - | 0.291 | 0.277 |

\[ Q_{w,\text{water}} = 15.84 \times 0.277 = 4.39 \text{ m}^3/\text{h}; \]  

(6)

### Table 3. Wastewater volume calculation.

| Wastewater type | Waterflow formation area, ha | Stormwater flow, \( Q_{w,\text{water}} \), m\(^3\)/h | Stormwater volume, ths. m\(^3\)/ha |
|-----------------|-----------------------------|----------------|-------------------------------|
| Stormwater      | 0.277                       | 4.39           | 0.66                          |

\[ V = 2,376 \times 0.277 = 0.66 \text{ ths. m}^3; \]  

(7)

\[ Z = C_1 / \text{MPC}_1 + C_2 / \text{MPC}_2 + \ldots + C_n / \text{MPC}_n < 1. \]  

(8)

At the same time, the general sanitary limiting index \( C_{\text{aux}} \) for suspended particle matters is set at \( \text{MPC} = 10.75 \text{ mg/l} \), and the fishery limiting index for petrochemicals is set at \( 0.05 \text{ mg/l} \), and the toxicological limiting index of MPC amounts to \( 0.1 \text{ mg/l} \).

### 4. Conclusion

To conclude, it should be noted that stormwater flowing from the enterprise pollutes not only the enterprise’s soil, but the surrounding territories as well.

An action plan for achieving the MPC level:

- Collection, as well as timely removal of urban waste from the industrial enterprise territory during the year to reduce the wastewater concentration;
- Activities that eliminate chances of petrochemicals spill when transporting goods during the year.
References
[1] Temporary rules for environmental protection from production and consumption waste in the Russian Federation 2004. Ecological Bulletin of the Moscow region 1-2
[2] Operating instructions for clearing bases, filling bases, pumping bases and nuclear power plants facilities 1997 (Moscow: GlavNefteSnab)
[3] Methodology for calculating concentrations of harmful substances contained in emissions of enterprises in the atmosphere 1998 (Moscow: Goskomhydromet)
[4] Yearbook of surface water quality and efficiency of activities on water protection on the territory of the Moscow State Research Center of Roshydromet for 1995 (Moscow)
[5] Belousov V N 2004 Designer’s Handbook (Moscow: Moscow University Publishing House) 96
[6] Rodionov S S 2014 Dissertation for the degree of PhD in Geography (Moscow: State University of Land Management)