MODELING IN THE SYSTEM OF ECOLOGICAL MONITORING OF RESERVOIRS

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Summary: *The increasing scale of environmental pollution, including water bodies, by various technogenic substances is the reason for environmental monitoring and the development of criteria for assessing the state of the environment. This paper presents a mathematical model of the maximum permissible discharge into water bodies.*

Key words*: pollution, water bodies, maximum permissible discharge, modeling*

The impact of man on the environment has sharply increased all over the world, and it has become apparent that the uncontrolled exploitation of nature leads to very serious negative consequences. The state of the biosphere changes under the influence of natural and man-made influences. However, there is a significant difference in the results of such actions: the state of the biosphere, which is constantly changing under the influence of natural causes, usually returns to its original state. And if we talk about the impact of man on the ecosystem, then it can lead to serious irreversible problems for certain subsystems of the natural environment.

Since environmental pollution is relatively “enclosed” within the territorial and economic regions, environmental monitoring is regional in nature. An indicator on the scale of the possible impact on the natural environment, where significant anthropogenic restructuring of the ecosystem is possible, is open water bodies. The water element of the environment largely determines the state of the environment as a whole. Therefore, it is very important to know the laws of pollution and their formation under the influence of natural and anthropogenic factors. One of the basic questions in this problem is the reaction of water resources to a changing anthropogenic load. Establishing the actual level of pollution of water bodies, which are complex objects of analysis, due to their exceptional multicomponent nature and a wide concentration range of elements, heavy metals is one of the most serious problems, especially in natural ecosystems, since they migrate from one ecosystem object to another, accumulating and sometimes causing secondary pollution [1].

Under the influence of pollutants, there is a shift in the natural equilibrium of a multicomponent system, such as natural water. A water body "mobilizes forces" that counteract the violation of natural conditions and seek to return the entire system to its original state.

The process of distribution of pollutants in water bodies and streams can be represented by scheme 1 (Fig. 1), which includes three zones of the mixing section: I – the jet (inertial) zone of the initial mixing, II – the concentration equalization zone (three-dimensional diffusion of the pollutant occurs in it, and when shallow depth – two-dimensional); III – zone of complete mixing (the so-called longitudinal diffusion of the pollutant occurs in it). Thus, impurities that have fallen into one or another part of a river runoff or reservoir are carried away by the current and, under the influence of turbulent mixing, are distributed into adjacent stream jets. In this case, the impurities are diluted, as they move away from the place where the impurities enter the stream, their concentration gradually decreases and, in the presence of self-purification, approaches the background [2].

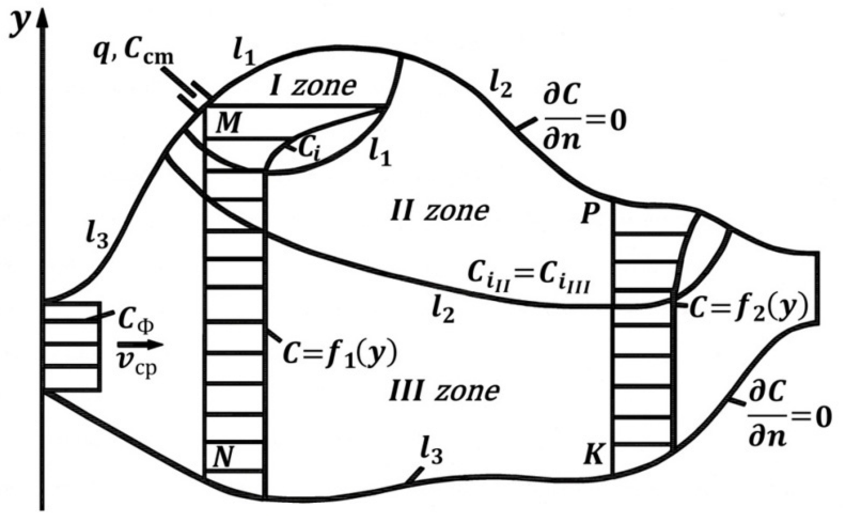

Fig. 1. Schematic diagram of the distribution of wastewater for water bodies

Self-purification is carried out under the influence of biological processes by oxidation of dissolved and suspended in water substances dissolved in it oxygen. This process is the result of the life of a whole complex of aquatic organisms. The aquatic micro flora is very diverse: bacteria, viruses, bacteriophages, molds and algae. Microorganisms play an extremely important role in the process of self-cleaning of water bodies. Microbiological processes during self-cleaning of water bodies occur as a result of bacterial nutrition, respiration and, finally, their death.

The change in the concentration of organic suspended solids is determined by two processes: precipitation and mineralization. As a result of the suspension of suspended solids in a pond, sludge is formed. In the sludge, as you know, there is a huge number of microorganisms (in 1 g of sludge up to 400-500 million microbes). Serobacteria are located in the surface layer of sludge. A number of benthic organisms – insect larvae, worms – feed on bottom silts and contribute to the transformation and mineralization of insoluble organic matter.

In order to partially eliminate future uncertainty, it is necessary to use mathematical forecasting. It consists in using the available information about the object of forecasting, mathematical processing of information by obtaining a relationship linking the characteristics with time or other independent variables and calculating the characteristics of the object at a given point in time for given values of other independent variables. The mathematical model for predicting water quality is based on the well-known semi-empirical equation of turbulent diffusion of pollutants [3,4]:

$$\frac{\partial c}{\partial t} + v_x \frac{\partial c}{\partial x} + v_y \frac{\partial c}{\partial y} + v_z \frac{\partial c}{\partial z} = \frac{\partial}{\partial x}\left(D_x \frac{\partial c}{\partial x}\right) + \frac{\partial}{\partial y}\left(D_y \frac{\partial c}{\partial y}\right) + \frac{\partial c}{\partial z}\left(D_z \frac{\partial c}{\partial z}\right) + \mu_c \qquad (1)$$

To solve equation (1), it is necessary to specify boundary conditions, i.e. set of initial and boundary conditions. As the initial condition for equation (1), the initial (at t = 0) distribution of the impurity concentration is taken:

$$c = c\,(x,y,z,0)$$

Boundary conditions (in the general case of the third kind) characterize the transport of matter through the surface restricting the flow. If q is the amount of substance transferred through a unit area of these surfaces per unit time, then at the boundaries of the studied object:

$$q_n = c v_n - D_n \frac{\partial c}{\partial n} \qquad (2)$$

In the expressions (1), (2): c is the concentration of impurities averaged over time; v_x, v_y, v_z, v_n are the projections of the time-averaged flow velocities in the x, y, z, n directions, respectively (the XOY coordinate plane coincides with the free flow surface, z is the applicate, n is the internal normal to the boundaries of the reservoir); Dx, Dy, Dz, Dn are the turbulent diffusion coefficients in the directions x, y, z, n, respectively; μ_c is the rate of physicochemical transformations, which in some cases can be represented as:

$$\mu_c = f_1 c \quad (3)$$

where f_1 is a parameter depending on the characteristics of physicochemical transformations.

In expression (2), the first term on the right-hand side determines the influx of impurities into the reservoir, due to the water velocities, and the second, the influx of impurities associated with the pulsation components of the actual velocities.

The distribution of impurities in ponds and watercourses from the moment they arrive should be considered as a single continuous process. In connection with the sufficient complexity of calculating the entire zone of influence of discharged effluents on the quality of natural waters, it is customary to consider three sections (Fig. 1). When studying the distribution of impurities in the zones marked in fig. 1, equation (1) can be used with certain assumptions. Due to the great complexity of solving system (1), (2) in engineering practice, simplified dependencies for conditionally selected mixing zones are most widely used.

Then, to calculate maximum permissible discharge (MPD) for the j-th polluting component:

$$MPD_j = g_B \frac{\hat{C}_B(\hat{C}_{MPD} + \hat{C}_{Ej} - \hat{C}_{Fj})}{100} - 3\sigma_{Bj}^2 \quad (4)$$

where g_B- parameter of the pollutant, $\hat{C}_B$- concentration of the j-th pollutant; $(\hat{C}_{MPD} + \hat{C}_{Ej} - \hat{C}_{Fj})$ – background characteristic of water quality; σ_{Bj} – is the variance of the process.

After calculating the MPD, the materials on the substantiation of the MPD should be systematized and formalized. To conduct a more detailed comprehensive forecast of the degree of pollution and the dynamics of the accumulation of pollutants in water bodies, it is necessary to develop models for predicting changes in the ecosystem, taking into account possible forms of transition (migration) of pollutants. In our case, the hydrosphere is the atmosphere (evaporation from water to the atmosphere), the hydrosphere is the land surface (the bottom of rivers, lakes) is the transition from water to soil (filtration, "self-cleaning", sedimentation to the bottom of water bodies). It is also necessary to take into account that one of the natural factors that can significantly change the concentration of chemical elements in enclosed bodies of water is the regime of precipitation. In dry years, due to a decrease in the water level, an increase in the concentration of chemical elements occurs, and in rainy years, on the contrary, their dilution occurs.

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