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ENVIRONMENTAL ASPECTS OF WATER SUPPLY SOURCES

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Annotation. **The article analyzes factors affecting reliability of operations of drinking water supply sources, and proposes a model for managing risk factors. The results of field studies are presented. The main functional purpose of environmental standards, as characteristics of the natural state of surface waters in the absence of anthropogenic load, is to assess the ecological well-being of water bodies to determine a set of water protection measures to achieve and maintain the specified water quality standards. Recommendations and guidelines for the ordering and organization of the territories of the three zones of the sanitary protection zone are proposed, as well as the rules for development and land use within the boundaries of the sanitary protection zone, taking into account its functional and intended use. Based on the results of field studies, three zones of sanitary protection zones were developed for capturing, considering the existing urban planning situation.**

Key words: **water supply, water intake, sanitary protection zones, risk, watercourse.**

FORMULATION OF THE PROBLEM

The distinct characteristics of drinking water supply in Donbass is that it is 97% based on surface sources and depends on their environmental safety. The increased risk and reduced safety for water supply systems is explained, first, by a decrease in water supplies; and second, by the deterioration of the quality of natural waters. 35% of the surface sources in the region today are not suitable for all types of water use.

The reasons for the emergence of risk might be due to technogenic and anthropogenic events. The main events include: floods, natural disasters, man-made disasters, terrorist attacks and the accumulation of toxins. Pollutants entering water bodies are very diverse and are difficult to neutralize [14-17]. For example, the half-life of some toxins is 80-100 years [1].

The current situation requires an integrated approach to assessing the safety of water supply sources and managing risks in watercourse systems.

RESEARCH ANALYSIS

In the process of monitoring the quality of natural waters, a large number of hydro-chemical and physio-chemical indicators are determined to characterize their pollution. However, there is a need for an integrated assessment of the contamination of drinking water supply sources by all parameters. The generally accepted approach to determining the quality of water by comparing the concentration of pollutants in water with the MPC values [2] does not give a clear idea of a degree of water bodies pollution, primarily due to the lack of interrelation of individual indicators. The MPC system at this time is subject to well-reasoned criticism, therefore, there has been a tendency to assess the state of water bodies not from the point of view of a specific nature management needs, but from the standpoint of preserving the structure and functional features of the hydro-ecosystem. This led to the development of a new environmental standard in the Water Code – an environmental standard for the quality of natural waters.

The main importance in ensuring the sanitary protection of water supply systems is tied to the sanitary protection zones (hereinafter ZZO). The sanitary protection zone (hereinafter SPZ) is an obligatory element of the subjects of economic activity. It should be noted that most approaches do not provide risk assessment and changes in the integrity of the SZO during the operation of structures and changes in the development of settlements.

In order to ensure the sanitary and epidemiological safety of the operation of water supply systems and their adaptation to modern urban planning standards and conditions of dense development it is necessary to further develop research on recalculating the WSS, considering the conditions of reliability and risk.

The purpose of the article is to analyze the current state of water supply sources and wastewater treatment plants, identify the main problems arising during the operation of zones in dense building areas and develop ways to preserve the sanitary and epidemiological safety of water supply facilities.

THE MAIN RESEARCH MATERIAL

Innovative studies of the state of water bodies show that virtually all water bodies, both surface and underground, are exposed to anthropogenic and technogenic factors.

Forecast of the water quality should be made in accordance to all standardized indicators and take into account the following: dilution of wastewater with watercourse water, destruction of non-conservative substances, formation of new intermediate products, self-purification, interaction of substances, neutralizing ability of a reservoir, salt hydrolysis, formation of poorly soluble compounds, sorption and desorption processes, temperature water quality and water quality management directly in the reservoir. In the process of monitoring the quality of natural waters, a large number of hydro-chemical and physio-chemical indicators characterizing their pollution are determined. However, there is a need for an integrated assessment of water bodies pollution for all measured parameters. The generally accepted approach to determining water quality is by comparing the concentrations of pollutants in water with the MPC values [6] does not give a clear idea of the total pollution of water bodies, primarily due to the lack of comparability of individual indicators. Today it is planned to establish MPD standards under which there will be no deterioration of water quality in the control section.

A number of scientists (AV Yatsyk, Susuma Kawamura, Henriet C. and others) put on the agenda the issue of strict monitoring the ecological state of fresh water bodies [7-11, 12]. The solution to this issue is aggravated by the fact that if the quantitative and qualitative nature of stationary changes in water quality in water bodies is generally studied and predictable, then in case of accidental emissions of pollution, the situation on watercourses can change very rapidly and unpredictably. Environmental safety can be improved by developing a model for predicting water quality, introducing environmental standards and risk reduction measures.

The main functional purpose of environmental standards, as characteristics of the natural state of surface waters in the absence of anthropogenic load, is to assess the ecological well-being of water bodies to determine a set of water protection measures to achieve and maintain the specified water quality standards.

To successfully solve problems related to forecasting, planning, operational management and quality control of the aquatic environment, a comprehensive description of hydro-dynamic, hydro-chemical and hydro-biological processes in water bodies is required. This description is provided using the methods of systems analysis and mathematical modeling.

The complex of programs «Sources of drinking water supply» proposed by the authors is intended for making decisions on reducing the risk in the system (Fig. 1).

Its individual blocks can be effectively used to solve a number of specific problems in design and water management practice. In the complex, the entire system allows you to determine a set of basic measures to improve the environmental safety of the source of drinking water supply.

Blocks are grouped by purpose:

- assessment of the condition of the source and selection of facilities for preliminary treatment of natural water;
- selection of the main structures of the waterworks, based on ensuring the required water quality.

The program is implemented for the MS DOS operating system (Figure 2).

Displaying the simulation results allows you to analyze and plan to reduce the risk in the watercourse and at the water intake.

Let's briefly consider some calculations of characteristics and processes.

Assessment of water quality at the source. The initial prerequisite for solving the whole complex of tasks to determine the environmental safety of the water supply system is to determine the limiting indicators of harmfulness by:

– group «general requirements» (1):

$$L_I = 0{,}2C_{O_2} + 0{,}17C_{БПК} + 0{,}03C_{в/в} + 0{,}14C_{pH} + 0{,}02C_{минер}, \quad (1)$$

where C_{O2} is the concentration of dissolved oxygen in water, mgO_2 / dm^3;

$C_{БПК}$ – biochemical oxygen consumption, mgO_2 / dm^3;

$C_{в/в}$ – concentration of suspended solids, mg / dm^3;

C_{pH} – pH value;

S_{miner} – total salt content, mg / dm^3;

– group «sanitary and toxicological requirements» (2):

$$L_{II} = 0{,}01C_{SO_4} + 0{,}01C_{Cl} + 0{,}25\,C_{NO_3} + 0{,}01C_{Cr}, \quad (2)$$

where C_{SO} is the concentration of sulfates, mg / dm^3;

C_{Cl} – chloride concentration, mg / dm^3;

C_{NO2} – concentration of nitrates, mg / dm^3;

C_{Cr} – chromium concentration, mg / dm^3;

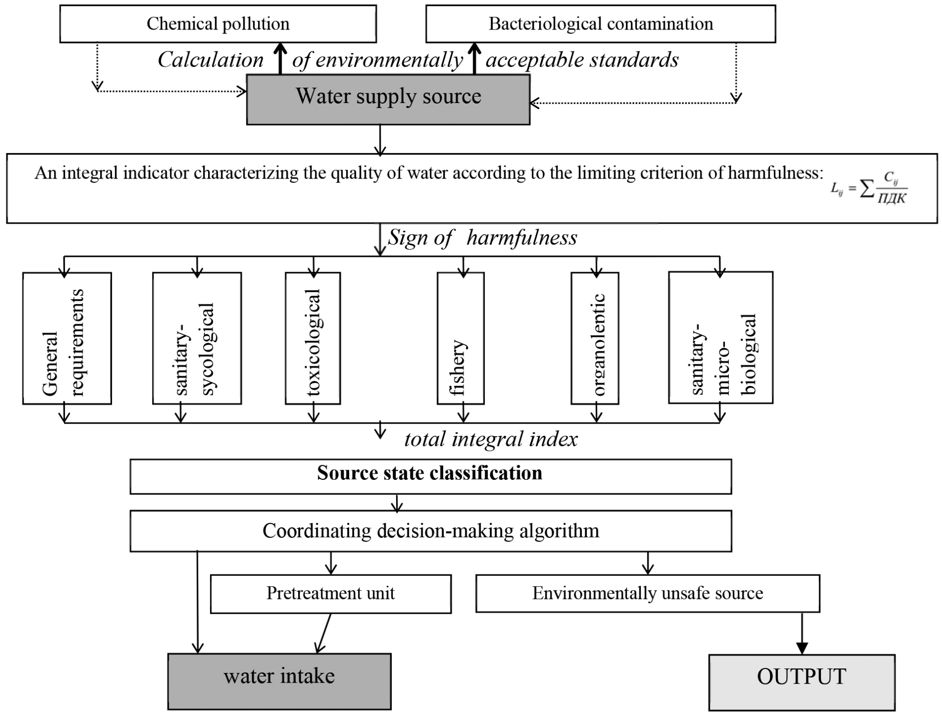

Figure 1. Diagram of the selection of the water intake system

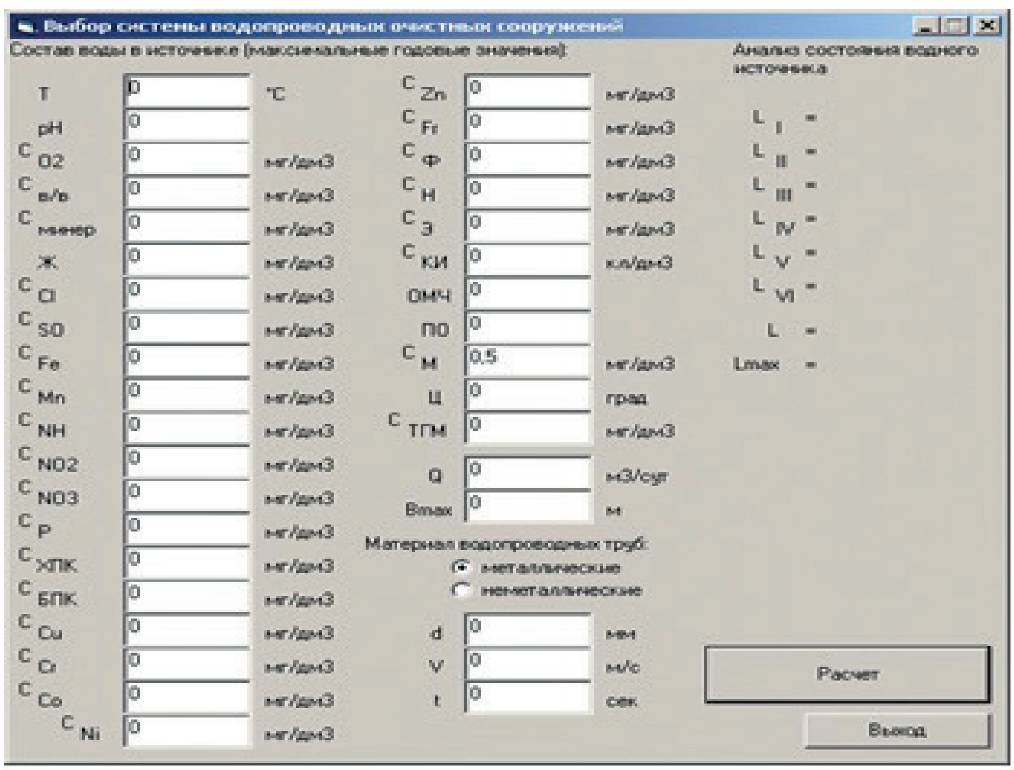

Figure 2. Outline of a water source risk assessment program

– group «toxicological requirements» (3):

$$L_{III} = 3{,}3C_{NH} + 100C_{NO_2} + 0{,}02C_{в/в} + \\ + 0{,}01C_{Cu} + 0{,}67C_{Zn} + 0{,}01C_{Ni}, \qquad (3)$$

where CNH is the concentration of ammonium nitrogen, mg / dm³;

C_{NO3} – concentration of nitrites, mg / dm³;

C_{Cu} – copper concentration, mg / dm³;

C_{Zn} – zinc concentration, mg / dm³;

C_{Ni} – nickel concentration, mg / dm³;

– group «fishery requirements» (4):

$$L_{IV} = 33{,}3C_{ф} + 12{,}5C_{н}, \qquad (4)$$

where

$C_{ф}$ is the concentration of phenols, mg / dm³;

$C_{н}$ – concentration of oil products, mg / dm³;

– group «organoleptic requirements» (5):

$$Lv = C_{Fe}, \quad (5)$$

where C_{Fe} is the concentration of iron, mg / dm^3;

– group «sanitary and microbiological requirements» (6):

$$L_I = \frac{C_{КИ}}{10000}, \quad (6)$$

$C_{КИ}$ – the number of bacteria of the group of Escherichia coli, cells / dm^3 and the total integral indicator (7):

$$L = L_I + L_I + L_{III} + L_V + L_V + L_V, \quad (7)$$

Based on the check, the following actions are selected:
– if L> 1, then the output (the system is not suitable for water supply),
– if L≤1, then the calculation is carried out further.

In water bodies, the ratio of production-destruction processes can be expressed by the quantitative dependence of pH and concentration of dissolved O_2, which follows from the scheme of the photosynthesis equation:

$$CO_2 + H_2O \overset{V_{фот}}{\underset{V_{десm}}{\leftrightarrow}} (CH_2O) + O_2$$

where $V_{фот}$, $V_{десm}$ are the rates of photosynthesis and destruction, respectively.

With an increase in the content of CO_2, the concentration of hydrogen ions increases, and the pH decreases, and vice versa. Consequently, in reservoirs, the ratio of the rates of production and destruction can be expressed by the dependence (8):

$$\frac{V_{фот}}{V_{десm}} = f\left(pH, [O_2]\right), \quad (8)$$

The authors [5] developed an integral indicator characterizing the balance of production and destruction processes in water bodies (9):

$$pH_{100\%} = \frac{\sum_{i=1}^{n} pH_i}{n} - \alpha\left(100 - \frac{\sum_{i=1}^{n} [O_2]_i}{n}\right), \quad (9)$$

where pH_i is the pH value over time t;
$[O_2]$ – concentration of O_2 (%), which is measured synchronously with pH during the same t, g/dm^3;
a – empirical coefficient of pH dependence on $[O_2]$;
n is the number of measurements during time t.

Using this algorithm, we estimate the main and intermediate states of the operation of the capturing settlement well. Geo-structurally, the underground water intake site is located in the central part of the Donetsk basin, northwest of the confluence of the Rossokhovataya and Korsun rivers (Figure 3).

The purpose of the capturing well is domestic water supply. Water is used for technical water supply and irrigation due to the non-compliance of its quality with the requirements of SanPiN 2.1.4.1074-01 «Drinking water. Hygienic requirements for water quality in centralized drinking water supply systems».

Based on the results of field studies, three zones of sanitary protection zones were developed for capturing,

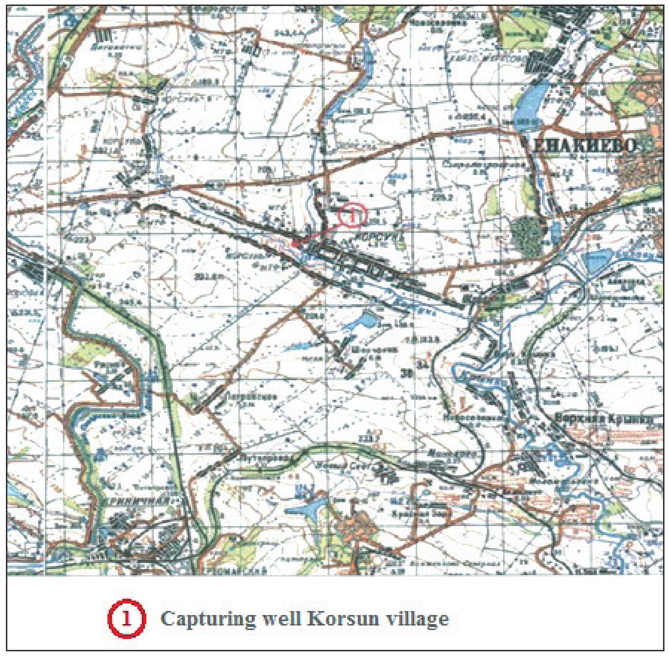

Figure 3. Situational plan M 1: 100,000

considering the existing urban planning situation (Figure 4), where the boundaries of the third zone of the ZSO are indicated in green, and the boundaries of the second zone are indicated in orange.

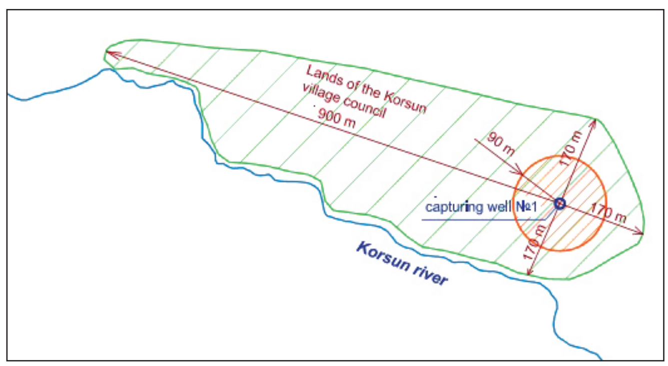

Figure 4. Scheme 2 and 3 of the ZSO belts

The boundary of the first zone of the WSS for an insufficiently protected source of groundwater should be removed from the well by 50 m. The length of the boundary is 345.4 m. The site with underground water intake facilities is in cramped conditions. Residential estate the building is located within the first zone of the WSS of the underground water intake. There is no centralized drainage of residential buildings.

Thus, in the course of the study, it was established that the sanitary protection zone of the underground water intake is not organized. In this regard, based on the current situation, it is necessary to carry out a set of measures to maximize the protection of groundwater from pollution.

The selection of data for the study of the state of the source was carried out at control points. The analyzed data were organoleptic, hydro-chemical, bacteriological and hydro-biological indicators, as well as the total salinity of water, the content of chlorides and sulfates. In terms of chemical composition, the groundwater of the Upper Carboniferous aquifer within the development of the

Araukarite suite is sulfate-hydrocarbonate; there are also hydrocarbonate-sulfate waters. Calcium and sodium predominate among the cations.

In terms of quality indicators, the water from the capturing well does not meet the requirements of SanPiN 2.1.4.1074-01 «Drinking water. Hygienic requirements for water quality in centralized drinking water supply systems». The main contribution to the composition of groundwater is made by infiltration waters of the Korsun River. It was established by statistical analysis that the main factors that stimulate eutrophication are the mineral forms of nitrogen (Nmin) and phosphorus (Pmin).

Knowing the normative value of the criterion for a specific water system, it is possible to calculate the EBC for various pollutants based on the multiple regression equation. Table 1 shows the EBC for pollutants in the water of the Korsun River.

Table 1.

EBC of pollutants for the Korsun river

Index	EDK, mg/dm³	MPC, mg/dm³	
		hygienic	fishery
Ammonium ions	1,0	1,0	0,5
Nitrite	0,1	0,1	0,02
Nitrates	1,6	10,3	9,1
BOD_{20}	3,0	3,0	3,0
Phosphates	0,1	1,1	0,2

The data presented in Table 1 show that the EBC differs from the hygienic and fishery MPCs. This indicates the need to strengthen control of nitrogen and phosphorus in the treated wastewater that enters the river. Korsun.

When calculating the maximum permissible discharge, the basic equation is used [4]:

$$qC_{ст} + \gamma \cdot Q \cdot C_{ф} = (q + \gamma \cdot Q)C_{к.ст}, \qquad (10)$$

where Q, q – respectively, the flow rate of water in a water body and wastewater;

$C_{ст}$, $C_{ф}$, $C_{к.ст}$ – respectively, the concentration of substances in wastewater, in a water body to wastewater discharge and in the control section, mg / dm³;

γ – mixing ratio.

The concentration of a substance in waste water is determined by the well-known formula [4]:

$$C_{ст} = \frac{\gamma \cdot Q}{q}\left(C_{к.ст} - C_{ф}\right) + C_{к.ст}, \qquad (11)$$

The permissible concentration of a pollutant in waste water (DCst) must meet condition (11), at which $C_{к.ст} \le$ ПДК:

$$ДК_{ст} = \frac{\gamma \cdot Q}{q}\left(ПДК - C_{ф}\right) + ПДК, \qquad (12)$$

Required degree of wastewater treatment (D%):

$$D = \frac{C_{факт} - ДК_{ст}}{C_{факт}} 100\%, \qquad (13)$$

With a large number of emissions and pollutants, such calculations often lead to non-realistic results when the concentrations become very low. According to the data in Table 2, the permissible concentrations of some substances in wastewater are much less than their permissible content in drinking water, that is, the discharge of even city tap water to the river should be prohibited.

Table 2.

Comparison of permissible concentrations of contaminants in wastewater with regulatory requirements

Contaminants	DC in wastewater, mg/dm³	SanPiN for drinking water, mg/dm³	MPC for water bodies of household and drinking water use, mg/dm³
Sulphates	360,0	500,0	500,0
Iron	0,3	0,3-1,0	0,3
A Aluminum	0,3	0,5	0,5
Ammonium nitrogen	0,2	–	1,0

In this case, it is necessary to introduce a comprehensive analysis with an assessment of economic and environmental risk. At the same time, it is necessary to apply economic criteria for the cost of control and measures to improve the quality of water, both natural and drinking. The methodological basis is the use of economic analyzes of the «cost-benefit» and «risk-cost» type [5].

In order to improve the quality of water, it is proposed to install floats – bioreactors upstream of the flow section (Figure 5).

Figure 5. Layout of floats – bioreactors in the section of the Korsun river

To find the optimal control mode for the quality of purified water, the method of dynamic programming is used. In general, the mathematical description of each stage of water treatment can be represented by a system of equations:

$$\left.\begin{aligned} x_1^i &= \varphi_1^i\left(x_1^{i-1}, u_1^i, \dots, u_r^i\right) \\ x_2^i &= \varphi_2^i\left(x_2^{i-1}, u_1^i, \dots, u_r^i\right) \\ &\dots\dots\dots\dots\dots \\ x_m^i &= \varphi_m^i\left(x_m^{i-1}, u_1^i, \dots, u_r^i\right) \end{aligned}\right\}, \qquad (14)$$

connecting the output parameters of the i-th stage x_k^i (k = 1, ..., m) with the output parameters of the previous stage xki-1 and the control parameters u_l^i (l = 1, ..., r) used at the i-th stage.

The dimensions of the state variables xi and control ui in the general case can be different for different stages of the cleaning process; moreover, when solving the system of equations, it will be assumed that

$$x^i \in X^i, u^i \in U^i, \quad (15)$$

where X^i, U^i are the regions of admissible variables x^i and u^i.

The efficiency of each stage of cleaning is assessed by the criterion of optimality – the amount of costs at each stage:

$$П^i = \psi^i\left(x^{i-1}, U^i\right), \quad 16)$$

The resulting assessment of the cleaning efficiency as a whole is determined as the total function of the costs obtained at each stage:

$$П_N = \sum_{i=1}^{N} П^i (x^{i-1}, U^i \to \min, \quad (17)$$

where $П_N$ is the minimum cost, which depends on the set of control actions at all stages of cleaning and which can be obtained from the expressions:

$$U_N^{опт} = \left(U_1^{опт}, U_2^{опт}, \ldots, U_N^{опт}\right), \quad (18)$$

Controlling influences in the process of water treatment can be: residence time at each stage of purification, speed of water movement, type and dose of reagent and sorbent, loading parameters, loading regeneration mode, and others.

Recommendations for the implementation of the three zones of the sanitary protection areas were proposed, and the rules for development and land use within the boundaries of the sanitary protection zone were formulated, considering its functional and intended use.

Conclusion: the availability of water is one of the fundamental factors that determine the possibility of developing settlements, economic growth. Security, environmental safety and reliability of water supply sources is the main task, solution of which requires an integrated approach, especially with organizing sanitary zones protection of water supply sources and water supply facilities in the conditions of the prevailing built-up areas.

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