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Improvement of electrical methods of control and evaluation of impact of military activity on surface waters

Abstract. *The article argues and describes a new approach to the technical assessment of the impact of military activity on surface water sources, which is based on new electrical indicators: Red-Ox, admittance; this will improve the processes of monitoring and responding to threats to the environment.*

Streszczenie *W artykule argumentowano i opisano nowe podejście do technicznej oceny wpływu działań wojskowych na źródła wód powierzchniowych, oparte na nowych wskaźnikach elektrycznych: Red-Ox, admitancja; usprawni to procesy monitorowania i reagowania na zagrożenia dla środowiska. (**Poprawa elektrycznych metod kontroli i oceny wpływu działań wojskowych na wody powierzchniowe)***

Keywords: electrophysical characteristics of liquids, Red-Ox, admittance, conductivity sensor, operational control
Słowa kluczowe: właściwości elektrofizyczne cieczy, Red-Ox, admitancja, czujnik przewodności, sterowanie operacyjne

Introduction

The purpose of water legislation of developed countries is to achieve sustainable use of water resources, including ensuring a satisfactory qualitative and quantitative state of surface and groundwater.

The legislation of such countries lays the foundation for a comprehensive water management system and requires union member states to set up appropriate administrative structures, develop plans and have a modern monitoring system. In addition, it sets standards for the quality of surface and groundwater in the environment, as well as for specific types of water use, standards for emissions of certain pollutants (eg nitrates), technological standards (eg for wastewater treatment).

The relevance of our research lies in the need for rapid and objective control of the composition of environmental facilities to minimize the impact of military activities on the environment, which is now the time.

The impact of military activity on the ecological state of the environment has been sufficiently studied in our country. Landfills and especially areas of actual hostilities are considered to be the most polluted.

Therefore, it is necessary to develop modern automated monitoring systems, electrical devices and methods of assessing changes in the state of surface waters for quick response. This is the purpose and task of the work.

The object of our research is the electrical properties of multicomponent liquids. The subject of the study is model multicomponent liquids based on water with non-electrolyte and electrolyte content and real objects of control: surface waters of the environment.

Novelty of research:

1. A list of the main chemical parameters was determined, the values of which approached or exceeded the normative limit values and, due to their origin, could be detected in surface waters during hostilities. There are 6 such indicators: total iron, ammonia, nitrites, phosphates, oxidizability and electrical pH. We refer to such pollutants as specific, as they are products of military activity in the processes of processing gunpowder, incendiary and smoke ammunition, fuel, brake and other technical fluids. The list of specific substances is compiled for each territory individually by chemical laboratories. Next, it is proposed to calculate and compare indicators of categories of quality and characteristics of natural water according to indicators of the water pollution index (IWP).

2. The method of assessing the quality of the source of drinking water, the Red Ox redox potential method, was experimentally substantiated and proposed. And the suggested values of this indicator for our quality categories.

3 Another novelty of research is the development of cyberphysical methods and means of operational control of the composition of surface water according to electrical input parameters. This method does not require laboratory research and large costs for the analysis of water composition

The water-liquid mixture system has non-additive electrical properties. In the case of using mixtures of substances of different electrical nature (high-resistance, low-resistance), which are found in the production of various industries, quick and selective analysis by existing conductometric and dielectric and other standardized methods is complicated. All these methods are non-selective, complicated and expensive, which makes it impossible to use them in automated control lines.

Scientific facts about the specificity of frequency dependences of multicomponent substances with the content of substances of different chemical nature have been obtained. The results of research using RLC-meters make it possible to establish the dependence of the electrical parameters of liquids in a wide range of frequencies of the electromagnetic field on the chemical nature and concentrations of their components. The use of established electrical parameters corresponding to standardized concentrations of components increases the informativeness of conductometric studies of multicomponent liquids. This makes it possible to expand the list of controlled substances with different electrical properties, to increase the selectivity, accuracy and efficiency of the analysis.

On the basis of the conducted research, the task of creating methods for determining the qualitative and quantitative composition of liquids was solved, which, due to a new electrical method, would allow to quickly control the content of the controlled substance in the liquid. It is selective, that is, it is designed to control individual components, and it is simpler than existing laboratory tests

Now we will consider the essence and research results of the methods proposed by us.

Research conditions

Regarding 1st item of research [1, 2], assessment of water pollution is carried out with the help of the integral characteristics of the water pollution control system IWP

$$IWP = (\sum_{i}^{6} C_i / K_i) / 6, \quad (1)$$

where C_i is the annual average value of the i-th indicator (measured at least five times a year); K_i is the maximum allowable concentration of the pollutant; 6 - the number of indicators, the values of which for a long time exceeded the MPC norms of the current standard of hydrophysical and hydrochemical indicators of water quality.

Such pollutants are formed in the process of military activity and are classified by us as specific.

Table 1. Categories of quality and characteristics of natural water in terms of the index of water pollution (IWP)

Quality categories	The meaning of the (IWP)
I- very clean	≤0,2
II- clean	>0,2-1
III- moderately polluted	1-2
IV- polluted	2-4
V- dirty	4-6
VI- very dirty	6-10
VII - extremely polluted	>10

The hydrophysical and hydrochemical indicators for all samples were determined and analyzed, and a list of the main indicators was obtained, the values of which were closest to the limit or slightly increased and could be caused by military activity. 6 such indicators were found: total iron, ammonia, nitrites, phosphates, oxidizability and pH indicator.

The received list of pollutants that can be formed during the activities of the troops was assigned to a number of specific, according to various forms of classification. Such pollutants are included in the number of obligatory specific pollutants. According to the standard formula for IWP, the calculation was made for all 5 samples and the average value was obtained: IWP = 1.23, which corresponds to the moderately polluted category (measurement in April 2021) and IWP = 4.8, which corresponds to the "dirty" category (measurement in April 2022).

Since, starting from February 2022, intensified military activity took place in the studied territory. Laboratory studies according to the method described above yielded significant excesses of the concentrations of the controlled substances determined by us, and as a result of the quality level assessment - "IV dirty".

In this way, we propose to evaluate the man-made impact on water sources not by the results of laboratory studies, but by the method of automated control with the help of electrical means of immittance measurement.

2. Let's consider the proposed method of assessing the quality of natural waters by therapeutic characteristics and its application.

The active reaction of water systems is interconnected with oxidation-reduction processes, which includes as a possible stage the transition of electrons from one group of particles to another. The process of rearrangement of electrons according to the valence states of the particles continues until a dynamic equilibrium is established, which corresponds to a certain oxidation-reduction potential — Eh.

The characteristics of the redox system can be obtained on the basis of the ratio of molar or ionic concentrations of the oxidized and oxidized forms of any substance in water. Eh and pH values affect various physicochemical and biochemical processes. Thus, in the process of oxidation, reduction, dissociation, or complex formation, by adjusting Eh and pH, it is possible to change the potential, direction, and speed of a chemical reaction, the redox activity of a substance in solution, the strength of complex compounds, in the case of biochemical water purification, to inhibit or accelerate the activity of microbial cell enzymes, etc.

Therefore, doctors and biologists believe that the negative value of Eh, which is lost during storage, is an indicator of the quality of natural water (table 1, table 2). For each such source, the value is individual, and can be measured (controlled) by a well-known laboratory instrument Ph meter.

Let's consider the proposed algorithm of the method of assessing the quality of the source for drinking water of the water source, the method of the oxidation-reduction potential of the ORP. We have established quality criteria based on Eh indicators for the selected specific source (table 2).

Table 2 Water quality criterion according to Eh indicators.

Water quality category	Eh
Higher	(-115) − 0
2d- category	0 – (+30)
3d- category	(+30) − (+60)

Let us consider the results of the research of a natural drinking source, the quality of which in April 2022, according to Eh, significantly deteriorated and cannot be called "medicinal", because this indicator acquired a positive value (table 3).

Table 3. Value of Eh, (mV).

Source number and measurement period	Background value 0 hours	1 hours	6 hours	12 hours	24 hours	48 hours
№5 April 2021	-115	-10	+5	+15	+25	+58
№5 April 2022	+46	+59	+71	+115	+125	+150

The research results indicate a change in the background value of the electrical indicator after the increased influence of military activity. A positive Eh value confirms the loss of therapeutic characteristics of the natural source, respectively, and the loss of quality (increase in the positive value) during storage.

3. For automated control of substance concentrations, the authors propose a new admittance method, which was traditionally used only for objects of an electrical nature (electric circuits). From this point of view, water, that is, aqueous solutions, are objects of a non-electrical nature.

The admittance method makes it possible, based on single positions, to build unified measuring devices for solving problems of qualimetry for various purposes. This is the construction of portable means for express control. Such tools should be accessible to a wide range of consumers both in terms of simplicity and price. Important indicators of the quality of such measuring tools here are: efficiency, low energy consumption, high portability indicators, uniformity of nodes.

The generalized structure of measurements of single indicators [3] of the quality of substances and materials of a non-electric nature is shown in Figure 1.

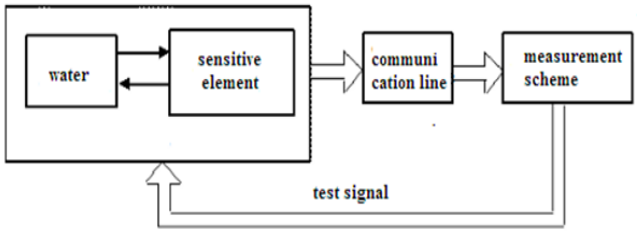

Fig. 1. Generalized structure of admittance measurements

The main units of the measuring device are an impedance sensor, a communication line and a measuring circuit. A substance or material together with a sensitive

element that is in direct contact with a physical quantity (its parameters) form an immittance sensor (primary transducer). Under the influence of the test signal parameters (level and frequency), it transforms a non-electrical physical quantity into an electrical quantity of a capacitive or inductive nature.

Figure 2. Laboratory installation of admittance measurements

With the capacitive type, the reactive component of the admittance acquires a positive value, and with the inductive type, a negative value [4-6].

Discussion of research results

The practical implementation of the admittance method to control exceeding the MPC occurs in the following way. The dependence of the active and reactive component of the conductivity of the solution of the reference sample of the studied liquid on the frequency of the electromagnetic field in the range of 50Hz to 100Hz is experimentally determined. at different volumes, starting with the smallest at the smallest immersion area of the transducer electrodes.

With the help of these dependencies, the frequency of the electromagnetic signal at which the reactive component is equal to zero is determined.

At the specified frequency, the dependence of the reactive component of the conductivity of the solution of the reference sample of the liquid under study on the volume of the poured liquid in the converter is experimentally determined, starting from the smallest one with the smallest immersion area of the electrodes of the electric converter.

Based on the constructed nomogram of the dependence of the reactive component conductivity on the volume of the reference solution or control sample, the volume of this solution in the converter, which causes a change in the polarity of the reactive component conductivity, is determined.

In the case of a higher concentration than the permitted one, the reactive component takes a negative sign or 0; in the case of a lower concentration - a positive sign.

Therefore, for the controlled normalized value of the concentration of a certain substance in a known solvent (matrix), the composition of which does not change significantly and does not affect the change in electrical parameters, there are values of the volume of the liquid and the frequency of the signal, at which the value of the reactive component is 0.

Thus, for a certain limiting concentration of a substance in a known solvent, there is a limiting value of the electrical index.

If the electrical analyzer is connected to the computer, after the preparation of the analyzer for work is completed, the name of the source and, if necessary, the numbers are entered into the computer's memory.

After connecting the transducer to the electrical analyzer of the control system, a change in the polarity of the controlled liquid at a certain value of the field frequency will indicate an increase in the given concentration of the controlled substance.

The results of measuring the concentration of the controlled substance are determined by the indication on the analyzer display and recorded in the measurement protocol.

Therefore, the basis for the implementation of a new electrical method of controlling the concentrations of controlled substances is the established grading dependence of the electrical indicator on the concentration of the controlled substance (Figure 3) [7-20].

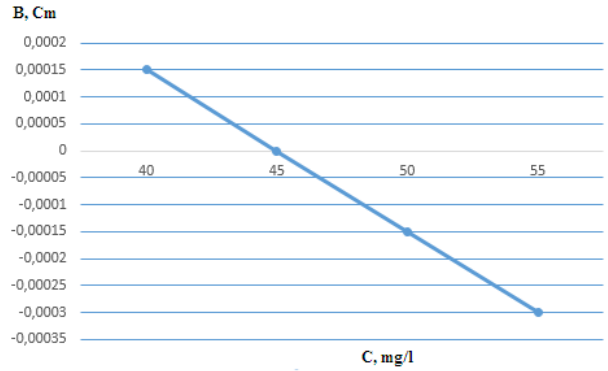

Figure 3. Grading dependence of the control of exceeding the permissible concentration of nitrates (45 ml/l) according to the measured values of the reactive component of conductivity.

Conclusions

As a result of our research:

- methods of surface water control were analyzed and a list of dangerous substances was established at one of the real objects;

an integrated method of water source assessment was developed and applied

- the application of electrical methods for research (Eh measurement and admittance measurement) is substantiated;

the Eh of real objects was investigated and the quality of real water sources was evaluated;

- the electrical parameters of water solutions in a multi-frequency electromagnetic field were investigated for the creation of surface water control systems based on electrical sensors.

The use of the proposed methods, methods of operational and objective control of the composition of water bodies of the environment will lead to the minimization of the impact of military activities on the surrounding natural environment, which is relevant at the moment.

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