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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

DEVELOPMENT OF SURFACE-ON-BOARD MEASUREMENT METHODS AND MEANS OF DOMESTIC AND PRODUCTION WATER QUALITY CONTROL

Speciality:	3337.01 – Information-measuring and management systems (ecology)
Fielt of science:	Technical sciences
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INDRODUCTION

The topic relevance and elaboration degree. It is known that now, in a period when the planet's population is increasing, the demand for drinking and domestic water continues to grow day by day, and up to 40% of the world's population suffers from water shortage. All these problems are directly related to the expansion of industrial areas and living environments, the development of new land areas, as well as the acceleration of the urbanization process. Taking into account the above, currently in world practice, measures are being taken to solve the problem of water shortage mainly in two directions:

–optimization of the rules for using clean drinking water resources;

–purification of polluted and industrially important waters, as well as improvement of methods for processing salty seawater.

In order to solve the considered problem, various researches are conducted in both directions, among which aerospace methods have a special place. Such methods allow for operational determination of water quality in water basins and various reservoirs on the basis of spectral reflection characteristics of water. At the same time, the improvement of spectrophotometric methods of the degree of water pollution will undoubtedly increase the efficiency of the procedures for the inspection and classification of natural drinking water resources in a wide area.

It is known that irrational earthworks, excessive use of nitrogen and phosphorus fertilizers lead to pollution of rivers, lakes and groundwater in general, which makes optimization of the principles of fertilizer use an urgent issue. The use of measurement data of reflected optical signals in issues such as monitoring the state of bottom sediments in drinking water reservoirs, minimizing the amount of heavy metals in water supplied to consumers, etc. is distinguished by its relevance. The development of new indicators and measurement methods for monitoring the level of pollution is one of the issues that attracts attention. Water purification from pollution using photocatalytic technologies, ozonation technology for the destruction of microorganisms, and improvement of applied measurement methods should also be noted as urgent issues. At the same time, the improvement of measurement systems to minimize the amount of chlorine used in water reservoirs is also an important issue. The issues of creating a control and measurement system to ensure the systematic sanitary condition of the water supply network of industrial enterprises, the establishment of a measurement complex to study the state of water in open water pools polluted by waste waters of mining complexes, and the optimization of the operating mode of such a system are also undoubtedly of relevance.

Thus, the dissertation topic, which is dedicated to the development of new measurement methods for determining the quality indicators of water resources, the optimization of water use procedures, as well as the improvement of the process of cleaning polluted waters, covers a very relevant problem.

The object and subject of the research. The object of the research is the control of the level and quality of water bodies' pollution, determination of water quality indicators, and a complex of issues of drinking water purification. The subject of the research is the improvement of on-board measurement methods and tools, determination of water quality indicators according to spectral reflectance characteristics, development of new methods and measurement systems for water quality control, optimization of control and measurement systems and tools for drinking water purification.

The purpose and objectives of the research. The main purpose of the dissertation work is to develop the scientific and methodological foundations of increasing the efficiency of the water quality control and measurement system, and to improve the operating mode of industrial and domestic water purification and water supply systems.

To achieve this goal, the following research questions were set and solved in the dissertation:

1. Development of a new concept and method for measuring total water pollution by applying an additional control indicator, investigation of the issue of constructing a wide-range meter of the level of chlorophyll pollution of seawater.

2. Solving the issue of forming optimal water flow in rural areas through the efficient placement of sources to minimize the concentration of nitrogen and phosphorus in the main water channel.

3. Solving the issue of determining the optimal temperature regime in the network of water supply pipelines to ensure the minimum amount of dissolved substances in the water supplied to consumers.

4. Investigation of the total amount of optical signal reflected from the bottom along the line from the shore of a turbid water basin to the depth.

5. Investigation of the possibilities of forming a new indicator of water pollution and development of a two-criteria extreme method for measuring the turbidity of drinking water by optical-electronic methods.

6. Optimization of the operating mode of the reactor network for water purification by photocatalytic methods.

7. Optimization of the operating mode of water purification by ozonation and chlorination methods.

8. Optimization of the operating mode of the measuring complex for monitoring and assessing the state of water bodies polluted by waste waters of mining complexes.

Research methods. Elements of the theory of measurement systems and optimization, scientific provisions of hydrophytic, mathematical analysis and physical optics were used to solve the problems posed in the dissertation. In order to verify the obtained theoretical results, the results of modeling carried out on the basis of natural and mathematical models were used. Also, the results obtained and approved during the conduct of known experimental work on the research topic were taken as a basis.

Main provisions put forward for defense.

1. A proposed new method and concept for measuring the level of pollution of water bodies based on the reflectance index of polluted waters. The principle of building a wide-range measurement system based on the limit value of the degree of pollution of seawater with chlorophyll “a”.

2. Rules for placing nitrogen and phosphorus sources in areas where surface flows are formed in agricultural production zones in order to minimize the nutrients transported by the main water channel, depending on the concentration of sedimentary substances.

3. Optimization problem for the minimum amount of dissolved solids in water supplied to consumers when the average daily temperature in the water supply network does not change and the network loads vary over time.

4. The provision on the extreme nature of the total signal reflected from the bottom of a turbid water body in the case of a certain functional dependence between the water depth and the attenuation of the optical reflection signal as it goes from the shore of the water body to the depth.

5. A new indicator of the level of water pollution in the form of a scalar polynomial equal to the quality index recommended by the World Health Organization (WHO), a proposed two-criteria optical-electronic extreme method for measuring the turbidity of drinking water and combined spectral optimization values.

6. Methods of purification of polluted water, procedures for optimizing the operation of the reactor network in photocatalytic purification and determining the ozonation mode.

7. The issue of determining the chlorine consumption in the chlorination procedures of reservoir waters with a number of simplifying conditions based on the first-order kinetic equation.

8. The issue of optimizing the operating mode of the measuring complex for monitoring and assessing the state of water pools polluted by strong point sources of heavy metal environments based on the Stern-Volmer model.

Scientific innovations.

1. A new method and concept for measuring the general pollution level, taking the water reflectance index as the main indicator, has been proposed. [8, 9]

2. The problem of optimal placement of sources of nitrogen (N) and phosphorus (P) in the opposite order to the concentration of sedimentary substances in order to minimize the transport of these

substances to the main water channel has been formulated and solved. [10, 17]

3. The optimal value of the water temperature in the water pipes of the water supply network and the time-dependent function of the network loads have been determined in order to minimize the amount of dissolved substances in the water mass delivered to consumers. [11]

4. It has been shown that, when moving from the shore of turbid water bodies to the depth along a certain route, the total reflection signal along the route can take a minimum value if there is a certain functional dependence between the attenuation of the reflection signal and the depth of the water. [1]

5. A two-criteria optical-electronic extreme method for measuring the turbidity of drinking water has been proposed. [3, 18]

6. It has been shown that increasing the amount of catalysts in the optimal organization of the operation of the reactor network of photocatalytic water purification is accompanied by an increase in the rate of photocatalysis, as well as an increase in the volume of water involved in purification. [12, 13]

7. The problems of optimal ozonation, chlorination and photocatalysis of water mass have been solved under certain simplifying conditions, and the solution of two optimization problems for determining the amount of chlorine consumed has been proposed. [5, 16]

8. The issue of optimizing the operating mode of the monitoring and measuring complex for the state of water bodies polluted by heavy metals from strong point sources was solved by introducing a new indicator (based on the Stern-Volmer model) that is inversely proportional to the concentration of heavy metals in water. [15]

Theoretical and practical value of the research. A new method for measuring the level of pollution based on signal indicators reflected from polluted waters, rules for optimal placement of potential pollutants such as nitrogen and phosphorus in the zones where surface flows are formed, minimizing dissolved solids in water, the extreme nature of the signal reflected from the coast to the depth, methods for measuring the degree of pollution, expanding the theoretical base to theoretical significance, the creation of automated systems for obtaining clean water using photocatalytic and ozonation methods, efficient use of cleaning agents, improvement of treatment facilities for chlorination of pools, collection of wastewater from mining complexes, monitoring the condition of pools, optimization of measurement modes, etc. are of practical importance.

Implementation of the research results.

- Experts recommended using the main results of the dissertation in assessing the condition of the pipeline route in the Oil Pipelines Department of the State Oil Company of the Republic of Azerbaijan, and in conducting corrosion monitoring of terminal areas (the act on implementation dated October 01, 2021 is attached to the dissertation).
- Among the main results of the dissertation, the development of the structure of the water quality control system (in the ultraviolet range) at Regional Water Canal Department No. 8 of the “Azersu” Open Joint-Stock Company and the use of the results of the solved optimization problems for the chlorination of water pools were recommended by experts (the act on implementation dated September 15, 2023 is attached to the dissertation).

Approval of work. The results of the dissertation work were discussed at the meetings of the United Scientific and Technical Council of the National Aerospace Agency (MAKA), as well as at the following scientific and technical conferences: XII International Scientific and Practical Conference "Aktualny problems of ecology and protection of work" (Russia, Kursk, May 20, 2020); Information systems and technologies: Achievements and perspectives. International Scientific conference (Sumgait, July 9-10, 2020); XIII International scientific-practical conference "Actual problems of ecology and labor protection" (Russia, Kursk, May 28, 2021);

Information systems and technologies: Achievements and perspectives. International Scientific conference (Sumgait, July 9-10, 2020); XIII International scientific and practical conference "Actual problems of ecology and labor protection" (Russia, Kursk, May 28, 2021); Automated control systems and information technologies. Materials of the all-Russian scientific and technical conference (Russia, Perm, 9-11 June 2021).

Published scientific works. 18 scientific works on the dissertation: 13 articles, including 5 in foreign journals (2 articles are included in the international database RSCI, 3 articles are included in the indexing database of the Russian Academy of Sciences), 5 works were published in the materials of scientific and practical conferences.

Name of the organization where the dissertation work was performed. The dissertation work was performed at the Institute for Space Research of Natural Resources of the National Aerospace Agency of the Ministry of Defense Industry.

Volume and structure of the dissertation. The dissertation work consists of an introduction, four chapters, main results, a list of literature used in 166 titles, appendices and a list of abbreviations. The total volume of the work is 156 pages, and the main volume is 136 (177963 characters) pages, including 12 tables, 49 figures. The introduction of the work consists of 13543 characters, Chapter I 34467, Chapter II 39090, Chapter III 34239 and Chapter IV 50958, result 5666 characters.

MAIN RESULTS OF THE DISSERTATION WORK

In the introduction, the relevance of the topic is substantiated, the main propositions, scientific innovation, the theoretical and practical importance of the work, the approval and application of the work are explained by defining the goals and objectives of the research.

In the first chapter, the issue of development of methods and means of water quality control in water bodies was considered, and the algorithm for the implementation of the proposed method for determining total pollution based on water reflection indicators was given. It has been shown that if the reflection indicator of water is selected at a specific wavelength, then its accuracy can be checked according to the additional control sign proposed in the base of the known Buger-Ber expression.

In this chapter, a joint surface-board spectral method for determining the concentration of chlorophyll “a” in sea water was proposed, using a wavelength range of 433-453 nm (blue zone) for spectrometric measurements of cartographic absorption coefficient and 510-530 nm (green zone) for measurements of chlorophyll concentration was considered appropriate. To determine the total amount of chlorophyll in water by remote sensing, the known correlation dependence[1] between its concentration in water (Chla) and the normalized differential vegetation index (NDVImod) was taken as a basis:

$$Chla(m\kappa g/l) = 139.37 - 491.01(NDVI_{mod}) - 6751.41(NDVI_{mod}^2) \quad (1)$$

Here, it is defined as $NDVI_{mod}=(NIR-B)/(NIR+B)$ and is a spectral reflection signal in the *NIR*-near infrared (IR) range and B in the celestial range. Thus, a surface-to-board method for determining the concentration of chlorophyll in sea water was proposed, and the algorithm's action procedure included the following stages (Figure 1). the principle of operation of the proposed complex is that areas where the level of pollution exceeds any limit values established by sanitary standards are determined by remote sensing (RS) method, and in this case it is recommended to undergo ground-laboratory measurements.
- selection of optimization criteria for given $\Delta Chla_{RS}$ (obtained by RS method), $\Delta Chla_{lab}$ (laboratory measurements), $Chla_{max}$ (maximum value) values of chlorophyll concentration;
- selection of concentration limit value $(Chla_{lim})$;
- carrying out on-board measurements according to the limit price;
- carrying out laboratory measurements according to the limit value.

$Chla_{lim}$ - the uncertainty of the determination of *Chla* in the implementation of distance measurements, which was carried out on the basis of the criterion of maximization of the total entropy of the optimal selection of the limit value

$$\Delta Chl_{RS} = \frac{d[Chl_a(NDVI_{mod})]}{d(NDVI_{mod})} \cdot \xi_{NDVI_{mod}} \quad (2)$$

designated as.

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[1] Johan B.F., Bin Mat Jafri M.Z., Hwee San L., Wan Omar W.M., Chun Ho T. Chlorophyll a concentration of fresh water phytoplankton analyzed by algorithmic based spectroscopy// The International Conference of Solid State Science and Technology (ICSSST 2017). Journal of Physics.

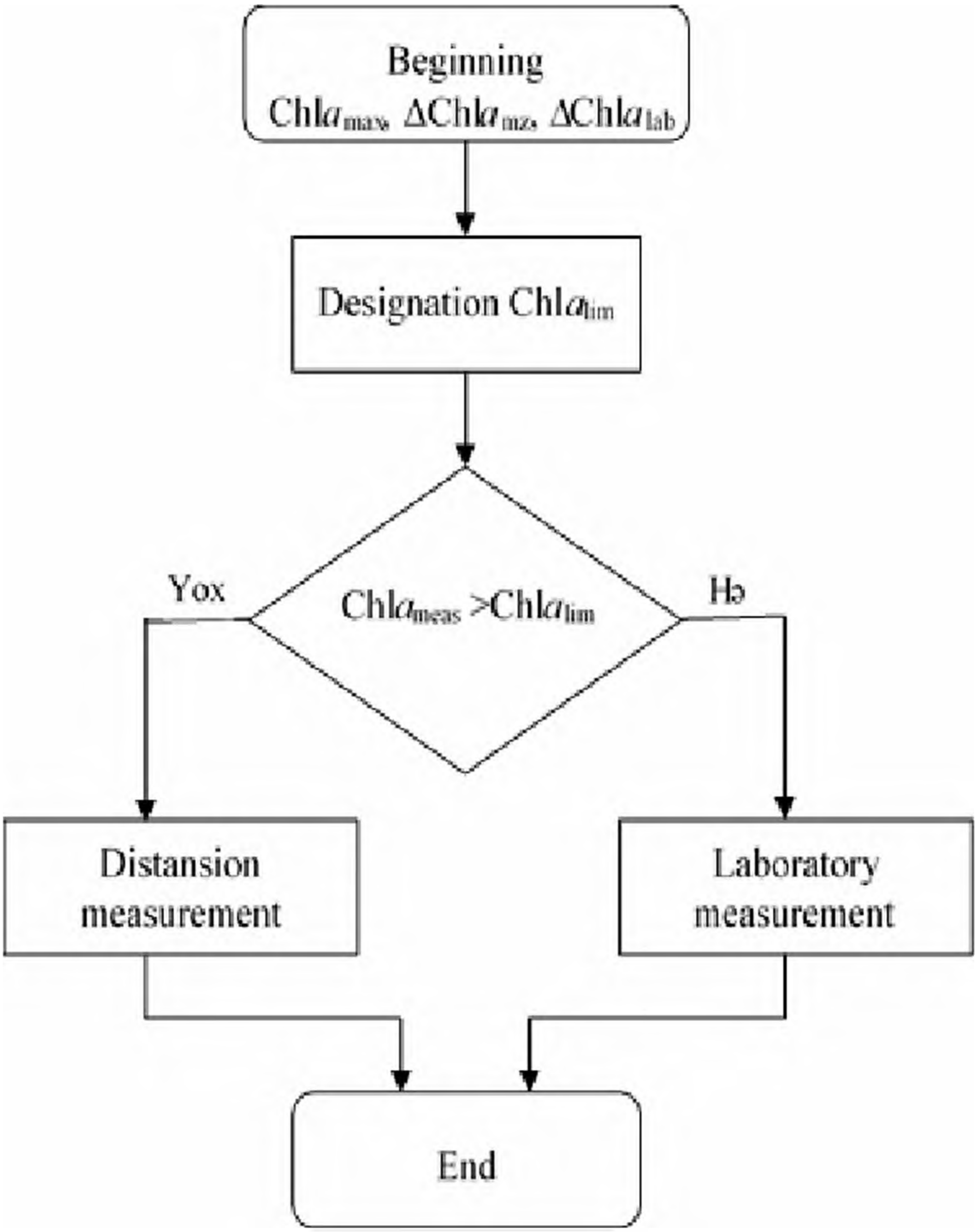

Fig. 1. Algorithmic presentation of surface-on-board measurement method of chlorophyll content in water

Where ζ_ (NDVI_mod) is the average quadratic tendency of the normalized differential vegetation index. Thus, the entropy of distancing measurements of the

$$Ent_{RS} = log_2 \left(\frac{Chl_{a.lim}}{\Delta Chl_{RS}}\right) \quad (3)$$

like, the entropy of laboratory measurements of $Chla$ while

$$Ent_{lab} = log_2\left(\frac{Chla.lim_{a.max}}{\Delta Chl_{a.lab}}\right) \quad (4)$$

designated as. Where $\Delta Chla_{RS}$-is the quantum quantity of the distance measurement system. The $F1$ criterion of the maximum of the sum of Ent_{MZ} and Ent_{lab} is defined as follows:

$$F_1 = \left(\frac{Chl_{a.lim}}{\Delta Chl_{RS}}\right) \cdot \left(\frac{Chla_{max} - Chla_{lim}}{\Delta Chl_{a.lab}}\right) \rightarrow max \quad (5)$$

For the $F1$ function to be maximized by

$$Chl_{a.lim.opt} = \frac{Chl_{amax}}{2} \quad (6)$$

it has been shown that its equality is paid. From the expression (6) it was found that the optimal limit value of $Chla$ does not depend on the quantities $\Delta Chl_{a.lab}$ and ΔChl_{RS}. In this way, according to the criterion of equality of entropies, $Chla_{lim}$ is derived from the expressions (3) and (4) to find the optimal quantity:

$$\frac{Chla_{lim}}{\Delta Chla_{RS}} = \frac{Chl_{max} - Chl_{lim}}{\Delta Chla_{lab}}$$

or

$$Chl_{lim.opt} = \frac{Chl_{max}}{1 + \frac{\Delta Chla_{lab}}{\Delta Chla_{RS}}}. \quad (7)$$

It has thus been shown, as expected, that the larger the ratio $\frac{\Delta Chla_{lab}}{\Delta Chla_{RS}}$ the $Chl_{lim.opt}$ price would be so small. Thus, the general concept of establishing a wide range meter of pollution of sea water with chlorophyll "a" has been developed, and fluent recommendations for determining the limit value for the transition to surface-laboratory measurement mode have been given.

The second chapter of the dissertation was devoted to the problems of determination of technological indicators of the water supply network by spectral and thermal methods, and the use of combined spectral optimization estimates was proposed to eliminate the uncertainty caused by the ambiguity of the spectral assessment. Then, in the same chapter, the synthesis of the optimal model of transportation of nutrients such as nitrogen and phosphorus in the rural area through surface streams to the main water pool was considered. The amount of member nitrogen transported to the main water channel

$$N_{org.S} = 0{,}001 \cdot C_{org.N} \cdot \frac{S}{A_{HRU}} \cdot \varepsilon_{N.sed} \tag{8}$$

as such, the nitrogen enrichment ratio is designated as.

$$\varepsilon_{N.sed} = 0.78 \cdot (C_{sed.S})^{-0{,}2468}.$$

Where $N_{org.S}$ – the amount of nitrogen transported to the main water channel (kg/ha); $C_{org.N}$ – concentration of member nitrogen in the 10 mm surface layer of the soil (metric tons); S – the amount of sedimentary substances per day (metric tons); A_{HRU} – the area of the hydrological unit of reaction (HRU) (ha); $C_{sed.S}$ – the concentration[2] of sedimentary substances in the flows of the surface $(mg/m^3_{H_2O})$.

The amount of phosphorus transported to the main water channel in the composition of the sedimentary mass (kg/ha)

$$P_{sed.sur} = 0{,}001 \cdot C_{sed.P} \cdot \frac{S}{A_{HRU}} \cdot \varepsilon_{P.sed} \tag{9}$$

as such, the phosphorus enrichment ratio is calculated as

$$\varepsilon_{N.sed} = 0{,}78 \cdot (C_{sed.S})^{-0.2468}$$

$C_{sed.P}$ – is the concentration of phosphorus in the sedimentary mass in the 10 mm surface layer of the soil (metric tons), S – the daily amount of sedimentary mass (metric tons), A_{HRU} – the area of the hydrological unit of reaction (ha), $C_{sed.S}$ – the concentration of sedimentary substances in the flows of the surface $\left(mg/m^3_{H_2O}\right)$.

Thus, a model scheme for optimizing the transport of N and P was presented, the following ordered sets for the i-th and j-cu components

[2] Tiruneh B.A. Modeling water quality using soil and water assessment tool (SWAT)// Environmental System Analysis and Management. A case study in Lake Nalvasha Basin, Kenya. March, 2004.

of the concentration of the sediment mass under the condition $A_{HRU} = const$ were adopted:

$$C_{sed.S} = \{C_{sed.S_i}\};\ C_{N,P} = \left\{C_{N,P_j}\right\};\ i = \overline{1,n};\ j = \overline{1,n} \quad (10)$$

Thus, variational optimization problems were solved to calculate the $C_{sed.S} = f(C_{N,P})$ optimal dependence of the concentration of nitrogen and phosphorus on the concentration of sediment material in the streams.

$$\int_{C_{sed.si.min}}^{C_{sed.si.max}} f(C_{N,P}) = C$$

within the limitation condition, the objective was formulated functionally, and the condition for minimizing the average integral quantity of pollution of water pools as a result of the solution of the problem by the Euler-Lagrangian method was determined.

Then, in that chapter, the issue of determining the optimal temperature regime, provided that the amount of solid sediment particles (TDS) in the water supplied to the population is minimal, was considered. In this case, it was assumed that water use depends on the hours of the day, the water temperature in the network changes during the day, and the average daily temperature remains unchanged (Figure 2).

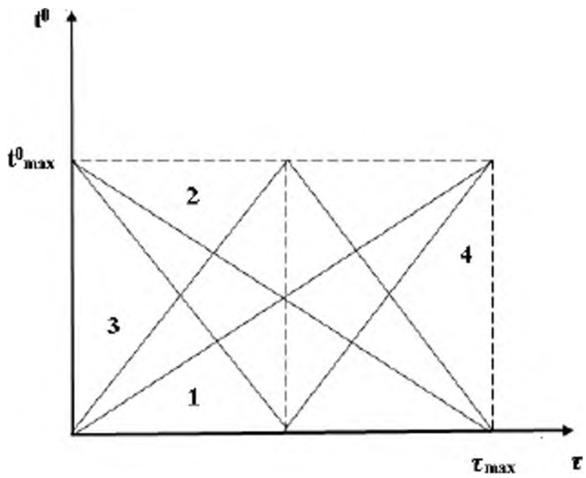

Figure 2. Graphs of water temperature changes during the day, while the average daily temperature remains unchanged: 1, 2, 3, 4– t^0 are options for changes

For the solution of the problem, it was considered that the compilation of overloads in the water pipeline network is a function of the current time. Thus, the daily current quantity of TDS was assessed, the objective of the problem of unconditional variation optimization under the above-mentioned limitation conditions was formulated functionally and the condition for reaching the minimum amount of TDS in the water transmitted to consumers was determined.

At the end of the same chapter, the extremity properties of the total reflection radiation in the turbid water on the "coastal-the center of the water basin" track were investigated. In the case under consideration, the question of what depth of water pools and what relationship between depth (z) and attenuation coefficient (k) exists, the extreme value of the sum reflection radiation (Rz) is solved. For this purpose, the case when the trassa passes from one depth of water to another was considered and the form of the relationship between z and k was determined to obtain an extremum value of RZ_{sum} sum reflection radiation. In the case under consideration, it was assumed that the indicators z and k are an ordered set, and the functional dependence of $K=K(z)$ between them was considered. Thus, the

$$\int_0^{z_m} k(z)dz = C \; ; \quad C = const. \tag{11}$$

reflection radiation within the limitation condition by depth

$$R_z = R_0 \cdot e^{-k(z)z} \tag{12}$$

it is obtained in the interval $(0 \div z_{max})$, knowing that it changes with exponential pattern such as:

$$R_{z_{sum}} = \int_0^{z_{max}} R_0 \cdot e^{-k(z)z} dz. \tag{13}$$

Thus, based on the expressions (11) and (13)

$$F = \int_0^{z_{max}} R_0 e^{-k(z)z} dz + \gamma \int_0^{z_{max}} k(z)dz \tag{14}$$

compiled with unconditional variation optimization function and

$$k(z) = \frac{1}{z} \, ln \, \frac{R_0 z}{\Lambda_0} \tag{15}$$

it has been shown that when the dependence is satisfied, the functional F reaches a minimum. Thus, when the nonlinear dependence between the depth z of the water basin and the attenuation coefficient k (15) of the reflected signal is satisfied, it has been shown that the total reflection radiation from the coast towards the depth of the basin receives a minimum value, which characterizes the property of a basin filled with turbid water.

The third chapter of the dissertation comments on the issues of developing new methods for diagnosing the level of pollution of Water Resources. A new indicator presented in scalar polynomial form was proposed on the basis of two pollution indicators such as Quality Index and multifactor regression assessment recommended by the General Health Organization of water bodies (who). Then from the known[3] Water Quality Index for assessing the quality of water bodies characterized by multicomponent pollution used:

$$WQI_{NSF} = \prod_{i=1}^{n} P_i^{\propto_i} \qquad (16)$$

Where P_i is the i-th parameter of quality (1÷100); α_i (0÷1) is the i-th parametric weight coefficient. It has been hypothesized that the watershed is contaminated with two pollutants whose concentrations are P_1 and P_2. The total level of pollution of water in it,

$$\beta_2 = P_1^{\alpha_1} \cdot P_2^{(1-\alpha_1)}$$

it was required to find the functional dependency $P_1=f(P_2)$, defined as,

$$\beta_1 = \int_{P_{2min}}^{P_{2max}} f(P_2)^{\alpha}: P_2^{(1-\alpha_1)} dP_2 \qquad (17)$$

the goal is to get a functional extremum value. The problem was solved by Euler's method and for the goal functional to get the maximum value $P_1 = \sqrt[\alpha_2]{\frac{2C}{P_2^2}}$ it has been shown that his addiction is paid. Where $C=const$. Thus, for the Prevention of two-component pollution of the watershed, it was recommended to achieve non-satisfaction of the indicated dependence between P_1 and P_2.

[3] Finotti A. R., Finkler R., Susin N., Schneider V. E. Use of water quality index as a tool for urban water resources management. 2015.

This chapter also proposed a two-criterion method for determining the turbidity of drinking water, the intensity of light at the output of the turbidimeter

$$I_{out} = I_0[e^{-\propto_a \cdot x \cdot c}] \cdot [e^{-\propto_b \cdot x \cdot c}] \quad (18)$$

presented as. Where I_0 - is the intensity at the input; x –the path of light in the aquatic environment; c – the concentration of the water sample; α_a – the absorption coefficient; α_b – the scatter coefficient.

In order to determine the turbidity of water, when the reverse scattering signal is high, the signal at the output of the research medium was taken into account to be low. An extreme method for determining water turbidity has been proposed. For this purpose (18) statement

$$I_{out} = I_0[e^{-\propto_b \cdot xc}] \cdot [e^{-\propto_a \cdot xc}] \quad (19)$$

proposed and schematic presentation for both cases is presented in Figure 3.

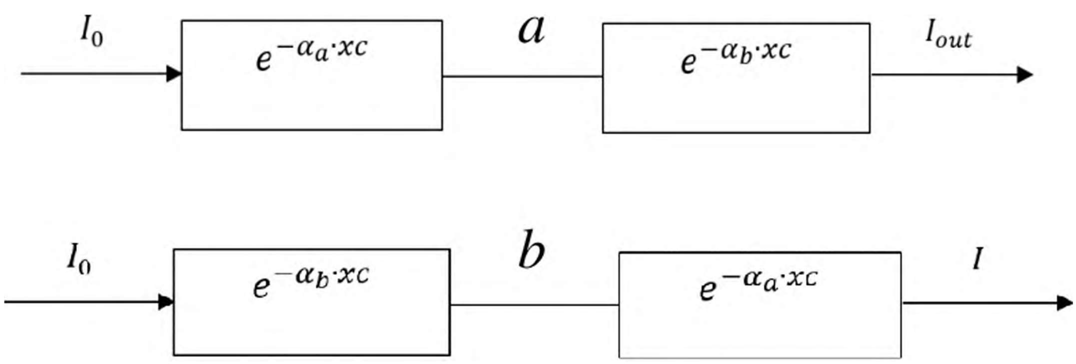

Figure 3. Procedures for changing the intensity of light in determining the turbidity of water: a) attenuation of the intensity of light due to absorption and scattering; b) failure of the non-scattered part of the light to be absorbed

Thus, the scattering part of the I_0 signal $I_{scat} = I_0 - e^{-\alpha_b \cdot xc}$ like, while the plural signal $I_{\Sigma_i} = I_{out} + I_{scat}$ designated as and

$$I_{\Sigma_i} = I_0 - I_0 e^{-\alpha_b x} + I_0\left[e^{-(\alpha_a+\alpha_b)xc}\right] \qquad (20)$$

expressed in the figure. In the expression (20) β_1 və β_2 $(\beta_1+\beta_2=1)$ weighting coefficients, and in the 1st approximation $\alpha_a = \alpha_b$ by accepting the final intensity calculated as,

$$I_{\Sigma_i} = \beta_1 I_0 - \beta_1 I_0 e^{-z} + \beta_2 I_0 e^{-2z}\ ;\ z = \alpha x c \qquad (21)$$

$$Z = ln\frac{2\beta_2}{\beta_1}$$

in solution, it has been shown to have extremum. Then by calculating the derivative of the 2nd order

$$\beta_1 < 4\beta_2 e^{-z}$$

when the condition is paid, it is shown that the expression (21) reaches a minimum, otherwise it receives a maximum price. Thus, the algorithm for measuring the concentration of water samples and determining pollutants the following procedural stages are covered:

- β_{1i} and β_{2i} is given, the signal (21) for the i-th period is formed;
- The quantity I_{Σ_i} is defined for the values $z_1 = \kappa_0$; $z_2 = \kappa_0 + \Delta\kappa$; $z_3 = \kappa_0 + 2\Delta\kappa$
- according to the selected values of z, I_Σ is measured and the presence of extremum is determined;
- if there is an extremum, the values of α, x, c are set;
- on the nature of extremum

$$\beta_1 < 4\beta_2 e^{-z}$$

  conditional checking;
- c, according to the known values of x, The TSS indicator and the turbidity of water are determined;
- if the extremum is not detected, then the next step $j=i+1$ is passed.

The structure of the operation of a practical device for determining the turbidity of water by the proposed extreme method is shown in Figure 4.

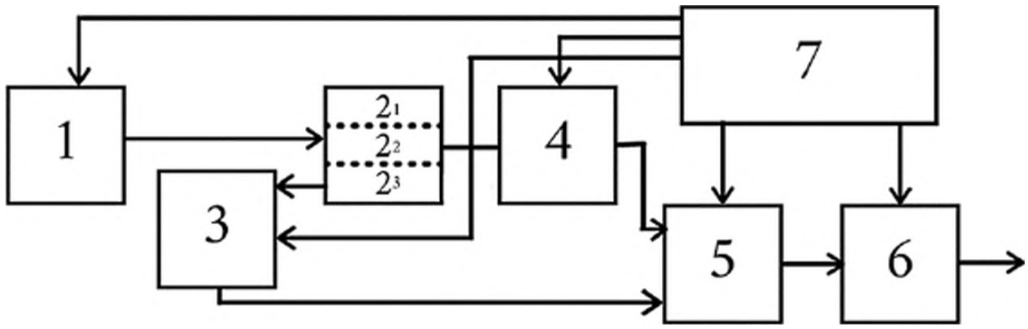

Figure 4. The structure of the device for measuring water turbidity: 1– Light Source; 2– 3 pcs cuvette with a water sample; 3– meter of light scattering on the contrary; 4– meter of attenuated light; 5 –block for detecting extremum in the general signal; 6 – formator of values; 7 – control unit.

The fourth charter of the dissertation is devoted to methods of purification of drinking and technical waters for various purposes. First of all, a multireactor method of purification of water from member pollutants using photocatalytic process was proposed. That method first compile $ln\left(\frac{C_0}{C}\right) = -k{\cdot}t$ t based on the equation of kinetics, subsequently $C = C_0e^{-k{\cdot}t}$ presented in the form of. Where k'– is the proportionality coefficient between the initial reactivity and the residual concentration of the compound (pollutant); C – the residual concentration of the compound; C_0 – is the initial concentration of the compound.

The dependence of the initial concentration (C_0) on the amount of photocatalysts introduced into the reactor (s) is as $C_0=f(S)$, and the dependence of the proportionality coefficient is as $k'=\varphi(S)$ presented as. Then the sum of the residual concentrations of compounds in the network of reactors

$$\sum_{i=1}^{n} C_i \cdot \Delta S = \sum_{i=1}^{n} f(S_i)e^{-\phi(S)t}\Delta S \qquad (23)$$

expressed in form (Figure 5).

Where $S_i=S_{i-1}+\Delta t$; $i = \overline{1,n}$; $S_0=0$; $\Delta S=const.$

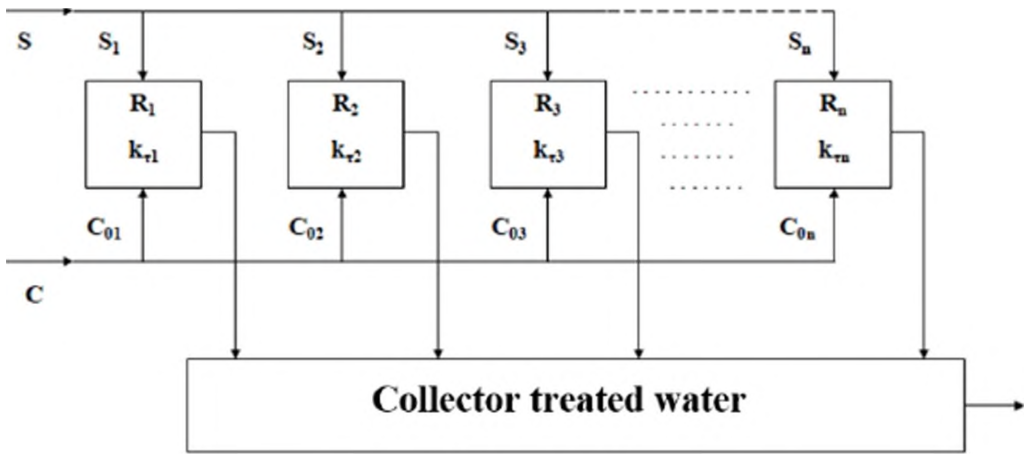

Figure 5. Structure of water treatment photocatalysis reactors ***(R_i, $i=\overline{1,n}$)*****:**
$S_i(i=\overline{1,n})$ **– the amount of photocatalysts;**
$C_{0i}(i=\overline{1,n})$ **– the residual amount of compound;**
$K_{\tau i}(i=\overline{1,n})$ **– the coefficient of proportionality**

From the expression (23), the total amount of pollutant components in water in the discontinuous case $F=\int_0^{S_{max}} f(S)e^{-\phi(S)t}\cdot ds$ of photoactivated catalyst stocks designated as $\int_0^{S_{max}}\phi(S)ds=C=const$ the problem of variation optimization within the constraint condition has been solved. It is thus shown that $\phi(S)=\frac{1}{t}ln\frac{f(S)\cdot t}{\lambda}$ when the solution is paid, the goal receives a functional minimum price.

Thus, an increase in the number of catalysts during the optimal organization of the work of the network of reactors should be accompanied by an increase in the rate of photocatalysis, as well as an increase in the volume of contaminated water under study. Then, in the same chapter, the procedures for ozonation of drinking water were considered, an indirect method of estimating the "assimilated member carbon" (AOC) in water according to the sign of change in the quantity of microorganisms was interpreted. It has been assumed that the amount of microorganisms remaining in water after ozonation is proportional to the quantity $N=N_0-\Delta N_1-\Delta N_2$. Where N_0 is the initial amount of microorganisms in water; ΔN_1 is the loss of microorganisms under the influence of ozone. Based on the Chika-Watson model of the deactivation of microorganisms and the kinetic model, the amount of AOC was expressed analytically, and the extremum was determined according to the concept of ozone (C_{O_3}) Thus it was revealed that,

$$C_{O_3} = \frac{1}{k_N \cdot \tau} \cdot \left(\sqrt{\frac{N_0 \cdot k_N \cdot \tau}{k_2}} - 1 \right) \quad (24)$$

when the solution is paid, the amount of AOC becomes maximum. Where k_N – is the deactivation constant of microorganisms, τ - is the absorption capacity of ozonized water, k_2 – is a constant number.

Thus, it has been shown that the ozonation regime carried out under the condition (24) cannot be considered satisfactory and should not be allowed in practice. Taking into account the stated, the 2nd optimization issue of ozonation was considered, n number of water sources with different initial amount of microorganisms *(N_0)* were investigated. It was required to find an interaction between the total amount of ozone used (TOD) and N_0 in such a way as to obtain an extreme value with a purpose function under certain limitation conditions. It was determined from the calculations that the total amount of ozone used when ozonizing a large number of different water sources should be distributed in proportion to N_0 on all water masses. Later in this chapter, the issues of treatment of reservoir waters with chlorine were commented, and the known expression[4] of the degradation coefficient of chlorine was taken as a basis:

$$k = F_{TB}(k_{ev} + k_s + k_{ok}) \cdot \theta^{(T-20)}. \quad (25)$$

Where k – is the degradation coefficient of chlorine at temperature T; k_s – is the speed of the photooxidation process; k_{ev} - is the evaporation coefficient; k_{ok} – is the rate of oxidation of free radicals of chlorine; θ – is the Arrhenius constant; F_{TB} – is the turbulence factor.

It was required to find such a moment of time $\theta^{(T)}$) that the amount of chlorine required for the processing of reservoir waters is

[4] Sarbatly R.H.J., Krishnaiah D. free chlorine residual content within the drinking water distribution system//International Journal of Physical Sciences. August 2007.

minimal. For the solution of the problem, the kinetic equation of the first order was used and

$$\gamma_1 = \int_0^{t_{max}} C_1(t)dt$$

the Integral Value of the amount of chlorine

$$\gamma_2 = \int_0^{t_{max}} T(t)dt = C = const$$

the extremum within the constraint condition was calculated. It was determined by the solution of the mentioned optimization problem,

$$T(t) = 20 + \frac{1}{F_0\theta_0 t} ln \frac{F_0\theta_0 t \cdot C_0}{\lambda_1}$$

when paid, chlorine consumption in the total volume receives a maximum price.

$$T(t) = 20 + \frac{1}{ln\theta} ln \frac{\lambda_2}{(ln\theta) \cdot t \cdot C_0 \cdot F_0}$$

the solution, on the other hand, indicates that a minimal amount of chlorine will be spent on water disinfection. Where $F_0=F_{TB}(k_{ev}+k_s+k_{ok})$; C_0 – the initial amount of chlorine, λ_1 ,λ_2 – are constants determined by the limitation condition.

At the end of this chapter, the scientific and methodological foundations of building a measuring complex for controlling pollution of natural water bodies near mining plants with heavy metals are commented on. In this case, the principle of attenuation of fluorescent radiation of dissolved organic substances excited by external radiation was taken as the basis. It has been assumed that a body of water (rivers, lakes, reservoirs, etc.) one power is contaminated from the source of production, and the method is proposed, the general realization scheme of which is shown in Figure 6. At the same time, it was recognized that there is the following nonlinear relationship between the formed complex and the degree of attenuation of fluorescent radiation (26)

$$\frac{F_0}{F_0 - F} = \frac{1}{f}\left[\frac{1}{K_m \cdot C_m} + 1\right] \quad (26)$$

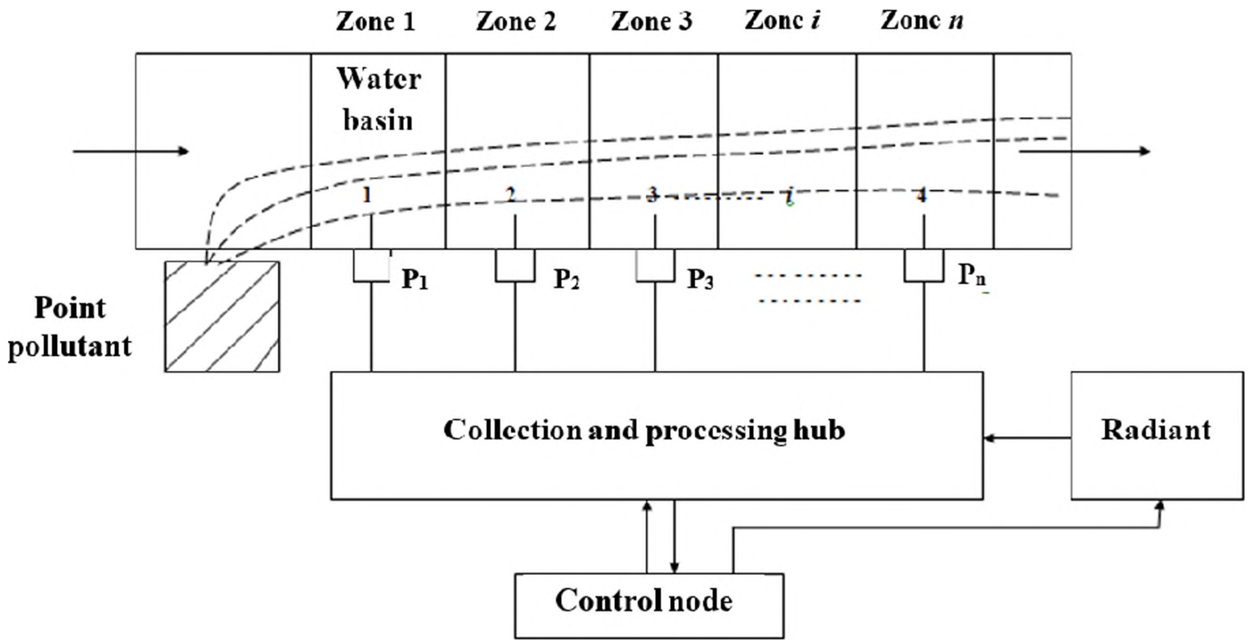

Figure 6. Scheme of implementation of the method of multipoint integral assessment of the level of pollution of a water body contaminated from one powerful source

$N_i(i=1,N)$ are observation points and the stern – Volmer model was used. Where F – fluorescent irradiation of dissolved member substances with metal ions; F_0 – the same, in the case when there are no metal ions; km – stability coefficient; C_m – concentration of metals; f-part of fluorescence, which is weakened by the action of metals. It was believed that when moving away from the point source of pollution, the concentration of heavy metals in the water also monotonously decreases. Therefore, the ratio $\frac{F_0}{F_0 - F}$ was taken as the main informative parameter, and $C_m = \{C_{mi}\}$; $i = \overline{1, n}$, of the activity of the measuring complex by accepting the set of it has been shown to be regulated by functional dependence.

$$\int_o^{C_{mmax}} \psi(C_m) d\, C_m = C = const \qquad (27)$$

The purpose of optimization with the acceptance of limitation condition is functional

$$\chi = \int_0^{C_{m\max}} \frac{1}{\psi(C_m)}\left[\frac{1}{K_m C_m}+1\right]dC_m + \lambda\left[\int_0^{C_{m\max}} \psi(C_m)dC_m - C\right] \tag{28}$$

Where λ – is the Lagrangian multiplication.

(27) some possible variants of the restriction condition satisfying function are presented in Figure 7.

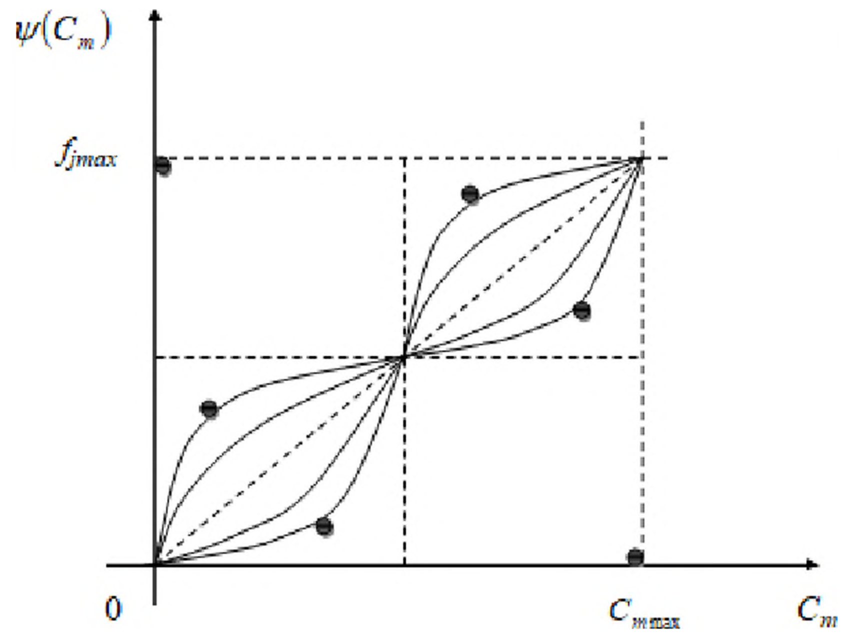

Figure 7. (27) possible variants of the function $\psi(C_m)$ satisfying the constraint condition

Thus, taking into account that the right side of the expression (27) is inversely related to the quantity C_m, it was required to find such a function $\psi(C_m)$ that the objective function x takes the minimum value. In turn, the minimum value of χ corresponds to the minimum value of y_i, and the maximum value of C_m. As a result, the solution of problem (28) was obtained as.

$$\psi(C_m) = \frac{C \cdot \sqrt{\left[\frac{1}{K_m C_m}+1\right]}}{\int_0^{C_{m\max}} \sqrt{\left[\frac{1}{K_m C_m}+1\right]}dC_m} \tag{29}$$

Thus, it was shown that the solution (28) determines the optimal mode of operation of the measuring complex, which controls the contamination of water bodies with heavy metals from the point source of pollution.

KEY CONCLUSIONS OF THE WORK

1. Based on the proposed new method and concept, the accuracy of the water reflectance value at a specific wavelength and an additional control indicator can be checked according to the degree of pollution of seawater. [8, 9]

2. The issue of minimizing the transport of nitrogen (N) and phosphorus (P) into the headwater channel and the optimal placement of the sources of these substances in the opposite order to the concentration of sedimentary substances has been solved. [10, 17]

3. By determining the optimal value of water temperature in water pipes of the water supply network and the time-dependent function of network loads, it is possible to minimize the amount of dissolved substances in the water mass delivered to consumers. [11]

4. When moving from the shore of turbid water bodies to depth along a certain route, the total reflection signal along the route may take a minimum value if there is a certain functional dependence between the attenuation of the reflection signal and the depth of the water. [1]

5. By applying the developed two-criteria optical-electronic extreme method, the efficiency of the process of measuring the turbidity of drinking water is increased. [3, 18]

6. Optimal organization of the operation of the reactor network of photocatalytic water purification - the volume of water involved in purification increases by increasing the amount of catalysts and the speed of photocatalysis. [12, 13]

7. By solving two optimization problems, the amount of chlorine consumed can be accurately determined by solving the problems of ozonation, chlorination and photocatalysis of the water mass. [5, 16]

8. The problem of optimizing the operating mode of the monitoring and measuring complex for the state of water bodies polluted with heavy metals from a strong point source has been solved. [15]

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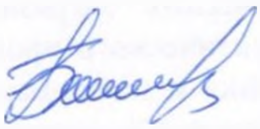

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