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SYSTEM OF WATER OBJECTS POLLUTION MONITORING

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ABSTRACT

The paper is dedicated to the development of system of water objects pollution monitoring. An efficient study of the environment situation and giving appropriate solutions related to its improvement require adequate information, obtained from a large number of various parameters measurements. Conducting of analysis more than 3-4 times per day is more economically efficient if automatic systems for environment monitoring are used.

Such system of water pollution monitoring proposed by authors consists of: computing centre that collects, process and analyzes the information received from the network of automatic radio beacons by the radio channel. Each radio beacon automatically determines the integral index of water pollution and transmits the results by the radio channel from the investigated place of water object to the computing centre.

The automated monitoring system can be used in a wide spectral range for registration of aqueous media parameters in hydro-physical and environmental studies, environmental monitoring of surface water parameters, in particular for suspended substances content measurement.

The system allows controlling light scattering characteristics for environmental monitoring of natural water-disperse media, measuring of brightness at different observation angles under deep-regime conditions, building spatial scattering indicatrix, which makes it possible to determine the ecological state of the water object and the nature of pollution processes.

Keywords: water, pollution, water monitoring, automated monitoring system, environment

INTRODUCTION

Water resources are one of the most important and at the same time the most vulnerable environment that can very quickly change under human influence. Pollution of water leads to the death of flora and fauna. An efficient study of the environment situation and giving appropriate solutions related to its improvement require adequate information, obtained from a large number of various parameters measurements [1]. Conducting of

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analysis more than 3-4 times per day is more economically efficient if automatic systems for environment monitoring are used. In such systems, the cost of information is 2-6 times lower in comparison to use of laboratory methods.

There are many papers [1–6] dedicated to the identification of the most significant polluting substances and to the development of high-quality devices for measuring their concentration in the aquatic environment. The relevance of such research is evident because these devices could help to control a huge amount of substances that are dangerous for the environment.

The need for such approach is also due to the fact that each year the number and location of pollution sources varies. This leads to decreasing of surface and underground water quality. Therefore, there is a need for in-time detection and evaluation of new sources of pollution.

To ensure proper environmental control of water quality, it is necessary to measure the pollution parameters and to have criteria for making decisions about environmental pollution by this parameter.

MATERIALS AND METHODS

The most widely used is automated control of light scattering characteristics of aqueous media, which involves the application of methods based on the direct measurement of optical parameters of the analyzed sample: refractometric and interferometric methods are based on refractive index measuring, absorption-optical method is based on absorption measuring, polarization and luminescent methods are based on optical activity measuring; nephelometric and turbidimetric methods are based on scattering measurement.

All of known optical analyzers have certain limitations in the case of application for light scattering media investigation. They include: impossibility of taking into account the effect of multiple dispersion, the need for multiple dilution of the sample prior to measurement, the complexity and duration of the sample preparation process. That leads to irreversible changes (transformation) of the sample, increasing the duration and complexity of measurement process [7].

In order to control light-scattering water-disperse media, the most expedient are automated systems of control, which combine set of measuring, computing and recording devices with definite functioning algorithms operating under the control of the operator. The main elements of such systems are as follows: measuring channels with primary measuring converters, information-communication channels, specialized computing devices or PCs, devices for recording, storing and displaying the information, etc. [1, 7].

Among the hydrological optical complexes for investigation of vertical structure of water, the best are sensor MARK III (Neil Braun), complex MGI-4103, a number of automated systems Meteor, Dolphin, Condor, Argos.

Analysis of existing systems shows that the most widely used are automated analyzers based on the discrete analysis method, the cassette type. Their advantages are as follows: elimination of mutual samples pollution, speed, coverage of wider range of chemical analyzes, etc. General point for all analytical systems is the modular construction, simplicity of service and compatibility of output signals with serial computing devices. Such systems differ by the number and composition of controlled parameters (most of them are designed for 6-10 parameters measuring). Automatic sampling is also used. Two methods are used for location of measuring unit: directly in water object or in special compartment, where the sample is fed from a given point of water object by submerged pump. The second way is more common.

The main obstacles to the use of existing systems for control the environmental parameters of water bodies in comparison to marine waters. Also the nature and spatio-temporal characteristics of hydrophysical fields distribution and pollution transformation processes significantly differs from those occurring in the marine environment. Therefore, there is a need to develop new devices of automated control of ecological research of water-disperse systems of relatively small surface water bodies.

The investigated aqueous media, according to their physical and chemical properties, belong to complex disperse light-scattering media consisting of small scattering particles distributed in a homogeneous medium (water). The application of the theory of light scattering makes it possible to calculate the attenuation, absorption, particle scattering matrix based on their refractive index. With these optical characteristics, it is possible to determine not only the function of particle size distribution in a dispersed medium, but also their shape, anisotropy degree, and complex index of refraction. Particularly interesting is the calculation of the light field in a dispersed environment, taking into account the polarization under the conditions of deep mode [1, 2].

RESULTS AND DISCUSSIONS

Automated system of water objects control

Taking into account that water objects are fast-changing thermodynamic systems, it is necessary for control system to obtain quantitative information directly from the object of control in real time without sample transformation. The developed automated system for monitoring the light-scattering characteristics of aqueous media is shown in Fig. 1.

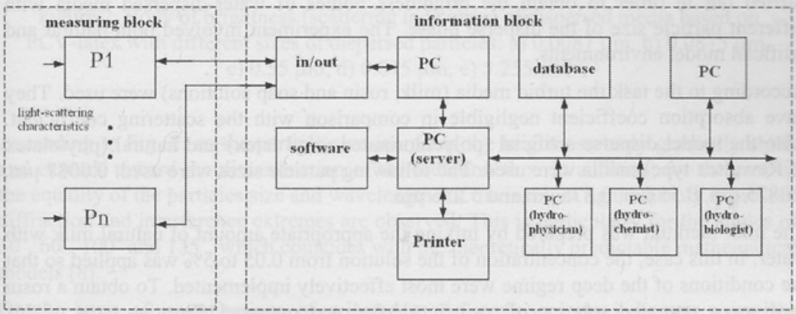

Figure 1. Automated system of water objects control

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It consists of two parts: measuring block and information block. The measuring block consists of radio beams located taking into account the hydrological characteristics of the investigated water object and parameters of possible sources of its pollution. The information block consists of PC with special software performing the functions of network server, which creates and maintains the database of the experiment, and set of necessary devices: network printer, processing devices and device of data displaying, etc.

In existing systems, the communication between measuring and information block is carried out through the device for the formation, transmission and reception of measuring information consisting of the transmitting and receiving parts connected by a cable line, fiber-optic channel or radio channel. The proposed automated system uses radio channel as it allows changing radio-beacon location very easy and in wide range depending on the tasks. Each radio beacon automatically determines the integral index of water pollution and transmits the results by the radio channel from the investigated place of water object to the computing centre. Inside the floating metal-plastic hermetic radio beacon there is an electrical control and switching unit, radio channel and power supply unit with connected electrical pump and unit of measurement. The last one is immersed in water at a certain depth. An anchor cable is attached to the radio beacon to hold it in the specified place of water object. Outside the radio beacon, an appropriate antenna is fixed accordingly to the radio transmitter frequency.

The received optical information about the light field state inside the light-scattering water-disperse medium under investigation is stored in the computer memory, where it is coordinated, processed and appears on the screen in different analytical or graphic forms. Further processing of the information is carried out using a neural network that recognizes the shape of the scattering indicatrix, compares it with known model indicatrices for certain types of contamination, which are stored in electronic database, and concludes about the possible water pollution.

The results of experimental studies of impurities in aqueous disperse media

A series of experiments using the automated control system under investigation were carried out in order to obtain the brightness bodies of water-dispersed media with different particle size of the disperse phase. The experiment involved both natural and artificial model environments.

According to the task the turbid media (milk, rosin and soap solutions) were used. They have absorption coefficient negligible in comparison with the scattering coefficient. Also the model disperse artificial (polychlorinated vinyl latex) and natural (phytolatex of Rewultex type) media were used. The following particle sizes were used: 0.0087 μm, 0.0875 μm, 0.55 μm, 0.875 μm and 5.255 μm.

The milk medium was prepared by mixing the appropriate amount of natural milk with water. In this case, the concentration of the solution from 0.05 to 5% was applied so that the conditions of the deep regime were most effectively implemented. To obtain a rosin medium, a saturated solution of rosin in alcohol was prepared. The two parts of this solution were mixed with one part of the alcohol, and then diluted with distilled water. The resulting rosin "milk" was mixed in the right amount with tap water. This method of preparation prevents coagulation of the rosin. When considering the rosin medium under a microscope, a large number of Brownian particles, as well as particles of irregular shape with different diameters were observed.

The soap medium belonging to colloidal media was prepared by dissolving soap in hot distilled water. The resulting solution was diluted with warm bidistilled water to the desired concentration, and then the medium was cooled to air temperature. PVC latex and phytolatex of Rewultex type were prepared according to the methods developed by the State Research Institute "Elastik" of the National Academy of Sciences of Ukraine.

The irradiation was carried out on the most characteristic wavelengths for the visible range: 450, 550 and 650 ηm. The received experimental bodies of brightness for a wavelength of 550 ηm are presented in Fig. 2.

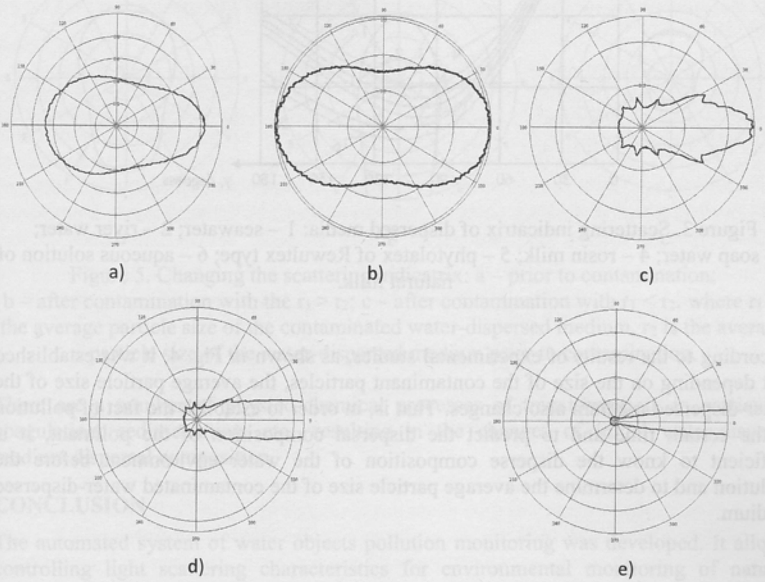

Figure 2. Body of brightness (scattering indicatrix) of dispersed media based on PCV-latex with different sizes of dispersed particles: a) 0.0087 µm, b) 0.0875 µm, c) 0.55 µm, d) 0.875 µm, e) 5.255 µm

According to Fig. 2, as the particle size increases the brightness body gradually shifts and extends toward the dissemination of the radiation flux. In addition, for the case of the equality of the particles size and wavelengths of the incident light, sharply expressed diffraction and interference extremes are observed. This is particularly for the angles of 30˚, 60˚, 100˚ and 135˚, which coincides with the theoretically predictable mathematical models [8].

On the basis of investigations of selected model environments indicatrix using the developed automated system, it has been proved that the patterns of radiation dissemination in the model environments are to a large extent adequate to real natural objects such as lake, sea, etc. (Fig. 3).

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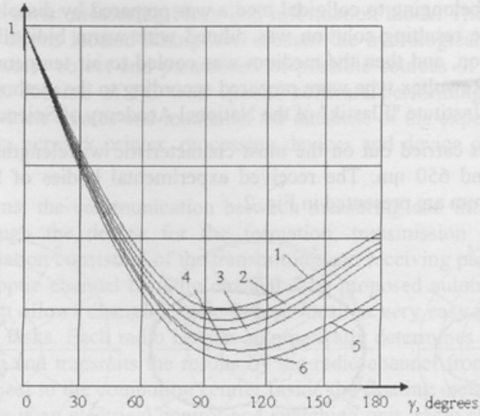

Figure 3. Scattering indicatrix of dispersed media: 1 – seawater; 2 – river water; 3 – soap water; 4 – rosin milk; 5 – phytolatex of Rewultex type; 6 – aqueous solution of natural milk.

According to the results of experimental studies, as shown in Fig. 4, it was established that depending on the size of the contaminant particles, the average particle size of the water-dispersed medium also changes. That is, in order to establish the fact of pollution at the certain time and to predict the dispersal composition of the pollutant, it is sufficient to know the disperse composition of the water environment before the pollution and to determine the average particle size of the contaminated water-dispersed medium.

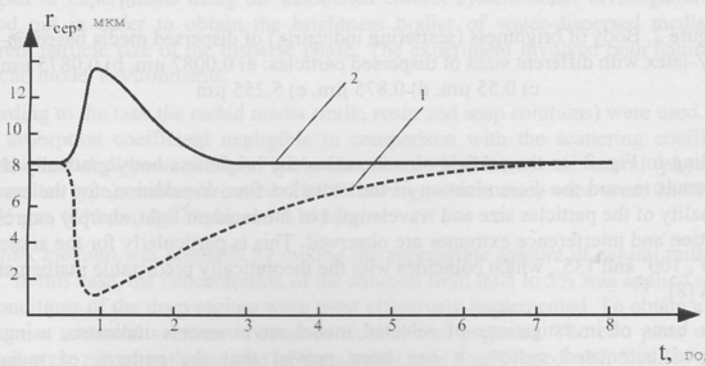

Figure 4. Changes of contaminant particles size (r_c) in polluted water with different dispersion of pollution: 1 – $r_c < r$ of water particles; 2 – $r_c > r$ of water particles

On the basis of the observations results (Fig. 5), one can also concludes that the scattering indicatrix and brightness body for contaminated water-dispersed media extend with the increase of contaminant particles size. After some time after the beginning of the pollution, the pollutants start to interact with the water-dispersed medium.

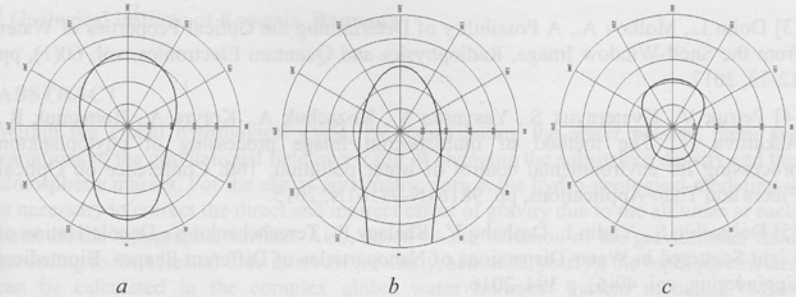

Figure 5. Changing the scattering indicatrix: a – prior to contamination; b – after contamination with the $r_1 > r_2$; c – after contamination with $r_1 < r_2$, where r_1 is the average particle size of the contaminated water-dispersed medium, r_2 is the average particle size of the water-dispersed medium prior to contamination.

There are a number of physico-chemical processes of transformation, in particular, coagulation, sedimentation, etc., resulting in the changes of initial water-disperse medium dispersal composition.

CONCLUSION

The automated system of water objects pollution monitoring was developed. It allows controlling light scattering characteristics for environmental monitoring of natural water-disperse media, measuring of brightness at different observation angles under deep-regime conditions, building spatial scattering indicatrix, which makes it possible to determine the ecological state of the water object and the nature of pollution processes. The main indicators for pollution measuring are scattering indicatrix and brightness body, which are extended with the increase of contaminant particles size for contaminated water-dispersed media. Thus, in order to establish the fact of pollution at the certain time and to predict the dispersal composition of the pollutant, it is sufficient to know the disperse composition of the water environment before the pollution and to determine the average particle size of the contaminated water-dispersed medium. The developed system can be used in a wide spectral range for the registration of aqueous media parameters during hydrophysical and environmental studies, for environmental monitoring of surface water parameters, in particular the content of suspended solids.

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