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Analytical Control of the Wastewater Treatment Process by a Generalized On-line Water Quality Index: Choice of Analytical Procedure and Development of Monitoring Technology

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Abstract—Rationalization and experimental confirmation of an efficient method of on-line waste water quality control using a generalized monitoring parameter, have been carried out, basing on the analysis and evaluation of modern technologies for industrial waste water quality control. A version of the practical processing of information intended for implementing the broadband spectroscopy for on-line quality control of the treatable water is described, as well as the structure and an example of the scheme of waste water treating device are presented, which include the system of operational control of water quality.

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INTRODUCTION

Analytical monitoring of wastewaters and emissions from environmentally hazardous sources with aim to promply reveal pollutants at levels higher than regulations allow is one of the main components of environmental protection activities.

Development of new-generation methods and tools of analytical monitoring calls for a new methodical approach. One such approach is provided by the determination of generalized (global) environmental quality indices.

Technical means of analytical monitoring should function in an automated regime to exclude human error risks. To ensure prompt decontamination of facilities and the environment, monitoring instrumentation should be able to image data on a display and transmit information to acquisition units for accumulation and registration, as well as formation and transmission of commands to operating mechanisms (sliding valves, stoppers, etc.).

The work presented in this paper is devoted to the problem of wastewater treatment. We substantiate a universal method of analysis of wastewater and present a generalized on-line wastewater quality index, and consider a rational technology of water treatment with continuous on-line water monitoring in key points of the treatment process.

Assessment of Modern Water Quality Control Technologies

Over the past century the methodology of water quality control has passed the way from organoleptic assessment (turbidity, color, odor, taste) to determination of a few tens of parameters (physicochemical, microbiological, levels of undesirable or toxic substances).

The international and Russian standards for water quality [1–5] are similar (in number, groups, and names of parameters). Drinking water should meet radiological, epidemiological, and chemical safety standards and have good organoleptic characteristics.

The requirements to the quality of utilized wastewater and sewage sludge in Russia are established by sanitary rules and norms [3]. About 40 parameters are recommended for monitoring in wastewater and sewage sludges, and half of them relate to the chemical composition of wastewater.

At present about 10 methods of water analysis are used: gas chromatography–mass spectrometry, thin-layer and paper chromatography, polarography, X-ray fluorescence, luminescence, chemiluminescence, and fluorescence photometry, atomic absorption and flame emission spectrophotometry. Experts consider that all these methods as promising and suitable for creating universal complexes (instruments) for analysis of multicomponent aqueous media.

The scope of accreditation of analytical laboratories includes more than 100 various chemicals in water, including all chemicals regulated by hygienic standards and sanitary rules and norms [2, 4, 5] for centralized and local water supply systems. Modern water analysis requires highly trained personnel, substantial material investments and methodical and technical support (procedures, standards, reagents, instruments, etc.), as well as a lot of time for analysis. Modern complexes for water quality monitoring are quite time-inefficient and require a lot of time to measure numerous parameters and acquire and process data; therefore, they are unsuitable for real-time monitoring of the quality of wastewater treatment.

Choice of Analytical Approach and Index for On-Line Water Quality Control

The task to organize on-line water quality control is gaining in importance for water treatment technologies including more than one process. The potential possibility of on-line control is provided by the requirement for the incoming wastewater and water passing through a series of treatment plants to meet special standards which are specific of each stage of the treatment process. For example, before entering the sorption plant water should be freed of coarse suspension agglomerates and before entering the UV irradiation plant, from mechanical admixtures and insoluble toxic hydrocarbons. Therefore, it is necessary to control in real time that the pollution level of water entering each treatment plant meets standards specific of this stage of the treatment process.

At present the research and technology problem to develop a high-performance on-line water quality monitoring system on the basis of a method capable of providing generalized assessment of water quality seems possible to solve.

On-line monitoring of water quality or failures (malfunctions) of separate components of water treatment systems requires methods having response times of about 1–10 s and capable of returning results in real time. Such requirements can be met by methods which would allow measurement of integrated water quality parameters in real time and automated making and implementing decisions (without an operator). Among these are such popular methods as photometry and spectrophotometry which are the most informative and universal.

Let us briefly characterize these methods.

Photometric methods measure the absorption (or transmission) of electromagnetic radiation of analytes or their solutions in the UV, visible, and near-UV ranges. The attenuation of monochromatic radiation depends on the concentration of the absorbent and the thickness of the solution layer (the Bouguer–Lambert–Beer law).

Photometric methods include photocolorimetry (visual photocolorimetry and photoelectric colorimetry with varied light filters), and spectrophotometry (with monochromatic light absorption).

Photocolorimetry measures the optical density of a colored solution at wavelengths of 400–760 nm (visible range). Visual photocolorimetry uses visual comparison instruments: colorimeters (comparators) and visual photometers, and photoelectric colorimetry uses photoelectric photometers (double-beam instruments with two photoelectric cells). The sensitivity of determination is 0.02–20 μg/mL sample, depending on the nature of the analyte.

Spectrophotometry measures absorption (or transmission) spectra. The sensitivity of the determination of elements and compounds is 0.08–10 μg/mL sample.

A particular case of photometry is nephelometry which measures the concentration of suspended particles by light scattering in the analyzed solution. Nephelometry shows a high sensitivity in strongly dilute solutions and compares in accuracy with other photometric methods (10–15%).

The schematic diagram of a photometer is given in presented in Fig. 1. The light sources are incandescent, mercury quartz, or hydrogen lamps.

The most appropriate method for the practice of water quality monitoring should provide the possibility to determine the entire set of pollutants. This is, for example, absorption spectroscopy (IR, visible, UV).

At present, we consider it real to develop an automated system for the assessment of water quality by a generalized index on the basis of wide-band spectrophotometry, a method which allows simultaneously measuring and integrating IR, visible, and UV absorption spectra. The feasibility and expediency of this method for generalized assessment of water quality is substantiated by the fact that most organic water pollutants (hydrocarbons, including the most ubiquitous water pollutants oil and oil products) show appreciable absorption in the UV range.

The required spectral range in spectrophotometers is selected by means of prisms and diffraction gratings. Light transmitted through the cell with a solution is received by a photoelectric cell which transforms light energy into electric power.

The limited use of this method in previous time was associated with the impossibility to obtain in real time the entire absorption spectrum of an analyte. The advent of miniature photoreceivers and their arrays has made it possible to measure nearly instantaneously absorption spectra in a wide wavelength range and thus lifted all restrictions for the use of wide-band spectrophotometry for on-line water quality control.

By the term "wastewater" we mean a mixture of wastewaters from domestic and industrial sources. Indus-trial wastewater contains such pollutants as phenols, hydrocarbons, amino and nitro compounds, chlorinated compounds, etc., and those of them that are environmentally hazardous are subject to regulation. In view of the fact that analysis of wastewater for each individual component is difficult and reasonably irrational, we consider expedient development and sophistication of equipment capable of measuring generalized water quality parameters. Among modern (but no on-line) generalized water quality parameters we would like to mention the total organic carbon. This parameter is determined by gas chromatography or IR spectroscopy and is a direct measure of the total content of organic pollutants. The total organic carbon offers certain advantages over indirect generalized characteristics of water pollution, such as biological oxygen demand (BOD) and chemical oxygen demand (COD), which are insufficiently accurate and long to measure. However, to determine the total organic carbon required complicated equipment and highly trained personnel.

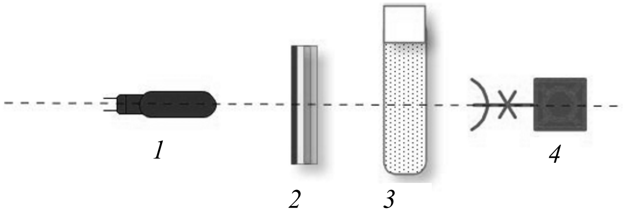

Fig. 1. Schematic diagram of a photometer: (*1*) light source; (*2*) light filters; (*3*) cell; and (*4*) receiver (light sensor).

Therefore, in the rationalization of the method and technology of on-line assessment of the quality of the wastewater being treated one should take into account not only reliability and information content of a generalized parameter and simplicity and time of analysis, but also simplicity of instrumentation. In our opinion, UV spectrophotometry of wastewater meets such requirements.

The potential of UV spectrophotometry in the assessment of quality of natural (river, sea) waters, as well as industrial wastewaters is presently under discussion. Correlations of UV parameters with COD and other generalized parameters have been considered.

The methodical approaches to the assessment of the quality of treated wastewater by UV absorbance (hereinafter, UV index) proposed in [6], were developed based on the results of testing UV spectrophotometry on waters from different treatment plants [6]. At 200–700 nm, strong absorption is characteristic of unsaturated and aromatic compounds (natural and synthetic), including phenols, acids, and other organic compounds. Inorganic compounds scarcely absorb in this spectral range. By measuring optical density (or transmittance) of wastewater sample at a certain wavelength and comparing this value with the regulatory standard for water at a concrete wastewater treatment plant, one can determine UV indices for different pollution levels of treated wastewater. The UV index can be used to control the level of organic pollutants in wastewater being treated.

There are certain methodical limitations to technical implementation of UV monitoring of wastewater.

The methodical limitations primarily relate to correlations between UV index and pollution level. The UV index will correlate with parameters that measure the level of organic pollutants (in particular, COD and BOD), only at a relatively constant average qualitative composition of wastewater. This method is suitable for large-scale treatment plants operating with a qualitatively averaged wastewater: In this case we can expect that the UV index will be proportional of the concentration of organic pollutants.

The UV index may prove difficult to establish for two reasons: turbidity of water and suspended solid particulate matter which scatters transmitted light and thus affects the optical density (UV index). Since suspended solid particulate matter generally consists of unsedimented particles of activated sludge which is an organic substance, then, theoretically, the turbulent UV absorbance of a sample is a measure of total carbon in activated sludge. The UV index correlates with the level of residual organic pollution of treated wastewater, when the engineering and technical conditions at the first treatment stage ensure efficient processing of wastewater for further purification (efficient separation of mechanical impurities at the primary treatment unit). After the first stage (primary treatment unit) the concentrations of suspended solid matter in treated wastewater should be lower than 35 mg/L. This limit allows efficient unit-to-unit quality control and realization of the wastewater treatment technology (control of water flow direction) by means of a system of hydraulic valves.

The UV index and COD (BOD) can also be affected by iron if its concentration in wastewater is higher than 2 mg/L. This effect can be accounted for by adding iron to the reference solution in concentrations detected in the samples. However, the concentrations of iron in treated wastewater generally do not exceed 1–2 mg/L, and such concentrations have almost no effect on the UV index.

The instrumentation of the UV method involves spectrophotometers of different brands. The UV index is measured at 254 nm in 10-mm quartz cells, using distilled water as reference.

In our experiments, a traditional scheme of quality control was used (sampling of water and sample preparation, preparation of instruments, measurement of the quality control parameter, data processing). The entire process took 10 min. Water samples were taken at the exit from secondary settling basins. The UV index was measured several times a day. For one measurement, 5–6 mL of wastewater was required.

The sample was loaded into a cell, and its optical density was measured at 254 nm (A_{254}). Since no regulatory standard for the UV index has still been established, the content of organic pollutants was estimated from the A_{254}–COD or A_{254}–BOD dependences obtained for the wastewater purified at this specific treatment plant. To construct these dependences, optical density and COD (BOD) measurements were performed for the same water samples taken for 10–15 days; the total number of samples was no less than 30–40. Samples were taken at different times of a day, when wastewaters of different degrees of pollution entered the plant.

In view of the fact that the error in COD, especially at low pollutant concentrations (>60 mg/L O_2), is relatively high (20–25%), this parameter was measured in conditions ensuring the negative effect of solid inorganic impurities and complete oxidation of organics.

The total organic carbon (C_{org}) determined by an independent method (for example, gas chromatography) correlates with the UV index. Moreover, C_{org} can be indirectly estimated from COD, because, as follows from our experience, the COD/C_{org} ratio in purified wastewater varies in the range 5–5.5.

As mentioned above, the UV index is a new optical parameter which, like COD and BOD, relates to the level of residual organic pollution of treated wastewater. It will be emphasized that at present the experimental UV indices obtained for wastewater samples from a specific treatment plant are impossible to interpret not having the COD and BOD values for the same samples. The quality of treated wastewater can only be assessed from experimental A_{254}–COD or A_{254}–BOD correlations.

Analysis of the results of testing of the method at different treatment plants show that the UV index, like C_{org}, is an objective measure of the quality of wastewater treatment. A lower C_{org} corresponds to a lower optical density and, vice versa, a higher C_{org} (and higher COD and BOD) generally correspond to a higher optical density.

It was experimentally established that the UV indices of treated wastewater have definite values that vary in a narrow range. At C_{org} in treated wastewater varying from 8–10 to 20–25 mg/L, the UV index varies in the range 0.20–0.75, which points to a good quality of water. At C_{org} = 15 mg/L (BOD 6–15 mg/L O_2, COD 40–70 mg/L O_2), the UV index varies only slightly, within 0.2–0.3. However, depending on the chemical composition of wastewater being treated, the absolute values of the UV index vary from plant to plant, i.e. at the same COD and BOD ranges the UV indices of wastewater treated at different plants can differ from 5–10%.

Presently, according to the procedure in [7], control of organic pollutants by the BOD and COD is performed once a decade. By measuring the optical density of water on a regular basis, several times a day, a more efficient control can be provided. If low optical densities characteristic of a specific plant are detected on a permanent basis, one can conclude that the plant provides the required level of purification of wastewater, and the treated water meets the regulatory standards. Increased UV index may imply either increased fraction of suspended particulate matter at the same concentration of residual organic pollutants or a volley inflow to the plant of hardly oxidizable (nonoxidizable) substances. Repeated measurement of the UV index and COD may provide clear evidence for a volley discharge of a highly polluted industrial wastewater.

Thus, the optical density (or transmittance) in the UV range serves as an indirect objective parameter indicative of the total organic pollution of wastewater discharges. It is to be said that modern technical solutions based on the UV monitoring of water quality have two essential disadvantages associated with the fact that water is sampled to a spectrophotometer cell which has been subjected to cleaning and stored in special conditions; analysis is performed on an instrument not built-in in the process scheme of treatment facilities, and this makes impossible on-line water quality control.

Thus, the development of technical solutions which would make possible express measurement of the UV index opens up the way to continuous on-line monitoring of water quality and control of water flow for efficient operation of treatment facilities.

The water treatment control system includes a unified water quality sensor and a valve system for controlling water flows depending on the quality of water. The schematic diagram of the on-line sensor for water quality monitoring is shown in Fig. 2.

The water sample flows through a quartz pipe which transmits the UV light from a UV lamp, the light passes through the water layer and detected by a receiver (photoresistor or another analyzer). The signal from the receiver is directed to a central control unit (CCU). The strength of the signal depends on the concentration of pollutants in water. The CCU sends a command to a shutdown system which directs the flow of water, depending on its quality, to the next treatment stage or returns it to the previous stage. For the actuators of the shutdown system, it is expedient to use two types of solenoid valves (normally open and normally closed).

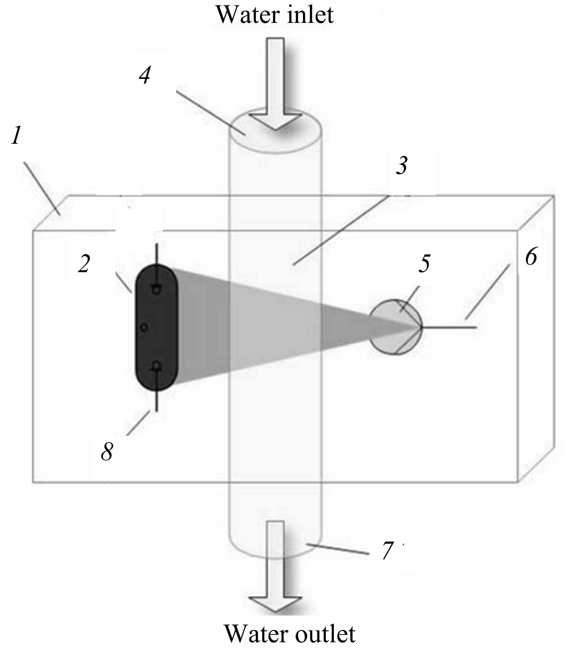

Fig. 2. Schematic diagram of the sensor for on-line water quality control: (*1*) housing; (*2*) UV source; (*3*) quartz tube; (*4*) inlet connection; (*5*) UV receiver; (*6*) CCU cable; (*7*) outlet connection; and (*8*) PSU cable.

Experimental Confirmation of the Use of Broad-Band Spectrometry for Water Quality Control

To check whether broad-band spectrometry is feasible for the assessment of water pollution, we measured the UV spectra of various water samples on a Specord M-40 spectrophotometer (Germany). In the experiments, we used a model organic dye solution, tap water from the Moscow water supply system (Central Administrative District), and wastewater from the Yauza River, taken near the Hospital Bridge.

It was found that the spectra in the range 200–300 nm allow determination of all water pollutants with the technically required accuracy. Therewith, part of the substances absorb in the visible spectral range (380–780 nm).

As seen from the spectra in Fig. 3, oil hydrocarbons and oil-based products (hexane and gasoline) show intense absorption in the region of 200 nm. The transmission curves of aqueous solutions of malathion group compounds (Fig. 4) have different patterns and configurations in the short-wave range.

The transmission spectra of solutions of a model organic dye in the raw and purified (fine, sand, and

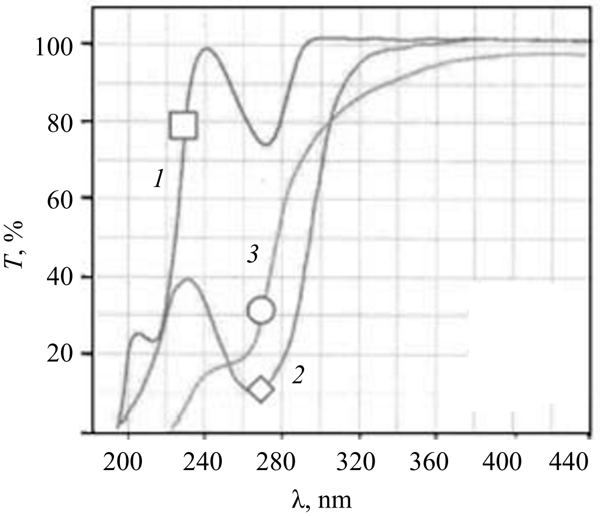

Fig. 3. Transmission spectra of colloid aqueous solutions oil hydrocarbons and oil-based products: (*1*) aqueous solution of phenol; (*2*) colloid solution of hexane; and (*3*) colloid solution of AI-95 gasoline.

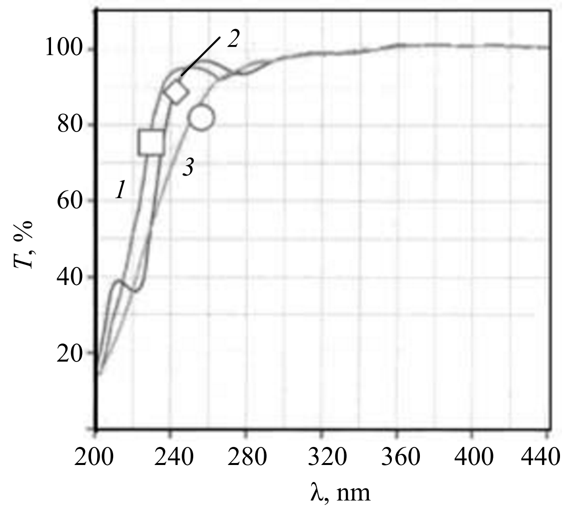

Fig. 4. Transmission spectra of aqueous solutions of malathion group compounds: (*1*) aqueous solution of phenol; (*2*) colloid solution of hexane; and (*3*) colloid solution of AI-95 gasoline.

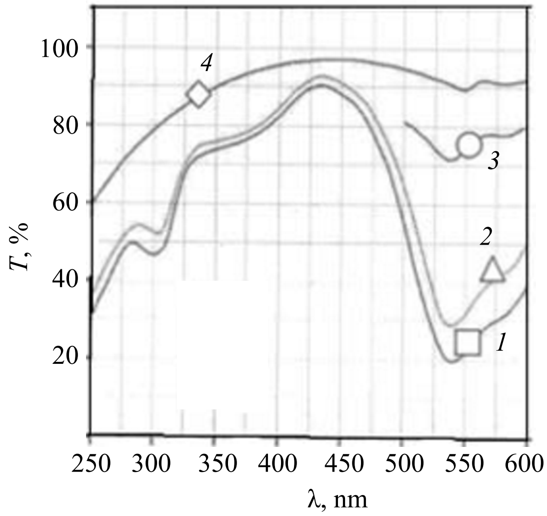

Fig. 5. Transmission spectra of a solution of a monoazo dye in tap water: (*1*) initial solution; (*2*) sample after a fine filter; (*3*) sample after a sand filter; and (*4*) sample after an ultrafine filter.

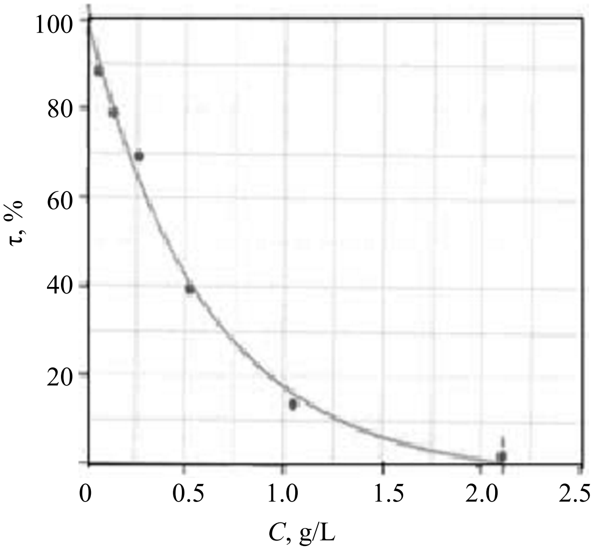

Fig. 6. Dependence of the transmittance (at 550 nm) of the model solution of an organic dye in distilled water on dye concentration.

ultrafine filters) tap waters (Fig. 5) display a characteristic visible absorption region (530–570 nm). Increasing spectral transmission time in this region is indicative of decreasing concentration in the water passed through the corresponding filter.

The experimental calibration curve for a solution of the dye in distilled water (Fig. 6) allows one to determine the dye concentration before and after treatment.

The results of short-wave UV transmission measurements for the raw tap water and that after ozonation and photochemical destruction of dissolved organic pollutants (Fig. 7) show that the informative spectral range is 200–300 nm. Increasing transparency of water in this range is evidence for decreasing concentration of dissolved organic pollutants.

As follows from the spectrophotometry results (200–700 nm) for the Yauza River water samples

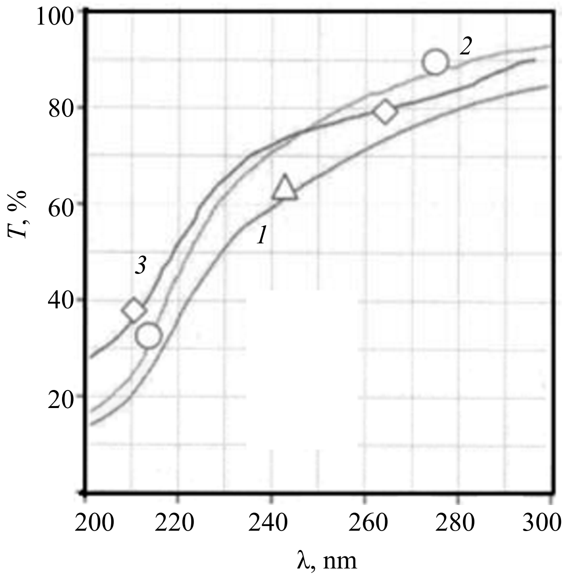

Fig. 7. UV transmission spectra of tap water: (*1*) raw water; (*2*) after ozonation (10 min); and (*3*) after treatment in a photochemical reactor (700 W, 10 min).

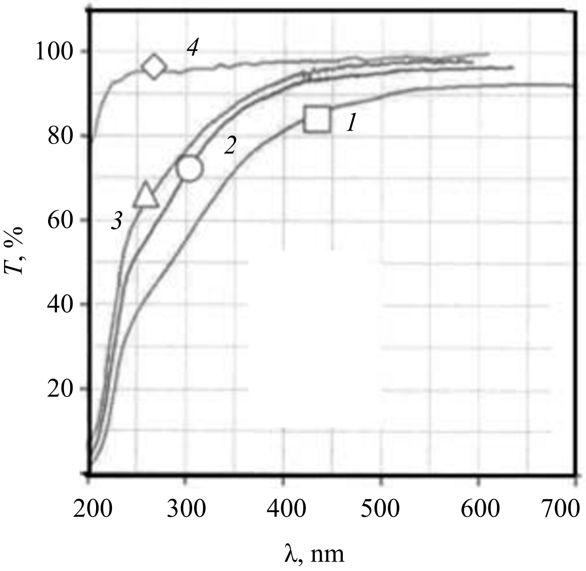

Fig. 8. Transmission spectra of wastewater from the Yauza River, purified by different treatment technologies: (*1*) raw water; (*2*) after ultrafiltration; (*3*) after ultrafiltration + photochemical destruction; and (*4*) after ultrafiltration + photochemical destruction + sorption.

before treatment and after treatment by a combined technology including ultrafiltration and photochemical destruction (Fig. 8), transmittance in the range 200–400 nm allows one to judge about the degree of water purification. It was established that the combined technology including exposure of water to broad-band UV pulses followed by passing through a sorption filter much facilitates operation of the latter. This result can be explained by the fact that the photochemical destruction products are better sorbed on the filter than the starting compounds. As a result, the effective sorption capacity of the filter in such water treatment scheme is used more completely.

The spectra presented here reveal a high sensitivity to the nature, state, and concentration of the solute. Naturally, the integral characteristics obtained by broad-band spectrometry, too, will reflect this sensitivity.

Thus, our results provide evidence for the feasibility of broad-band spectrometry for integral assessment of water quality.

Fast Photoelectric Sensor on the Basis of Broad-Band Spectrometry

We developed a fast broad-band spectral photoelectric sensor for on-line detection and monitoring of water pollutants. For continuous on-line water quality control the photoelectric sensor is built into the pipeline. Figure 9 presents one of possible designs of the photoelectric sensor.

The principal elements of the sensor are a flow cell with a pulsed xenon lamp placed eccentrically inside and two selective photoreceivers (photocells or photodiodes with correction filters for cutting the most informative spectral UV range.

Irrespective of what photoreceivers are used, the photoelectric sensor measures the intensity ratio of two signals (I_1 and I_2) which come to the photoreceivers by two channels.

The intensities of light signals are calculated by the formulas:

$$I_1 = I_0e^{-(k\mathrm{w} + k\mathrm{p}C\mathrm{p})L1} \text{ and } I_2 = I_0e^{-(k\mathrm{w} + k\mathrm{p}C\mathrm{p})L2},$$

where I_0 is the xenon light intensity before the beam of light passes through the solution; k_w, absorptivity of pure water; k_p, effective (total) absorptivity of pollutants in water; C_p, effective (total) concentration of pollutants in water; and L_1 and L_2, thicknesses of the light-absorbing water layer in the sensor.

From the intensity ratio of light signals

$$I_1/I_2 = e^{-(kw + k\mathrm{p}C\mathrm{p})(L1 - L2)} = e^{-k\mathrm{cont}(L1 - L2)}$$

we calculate a pollution (contamination) parameter by the following formula:

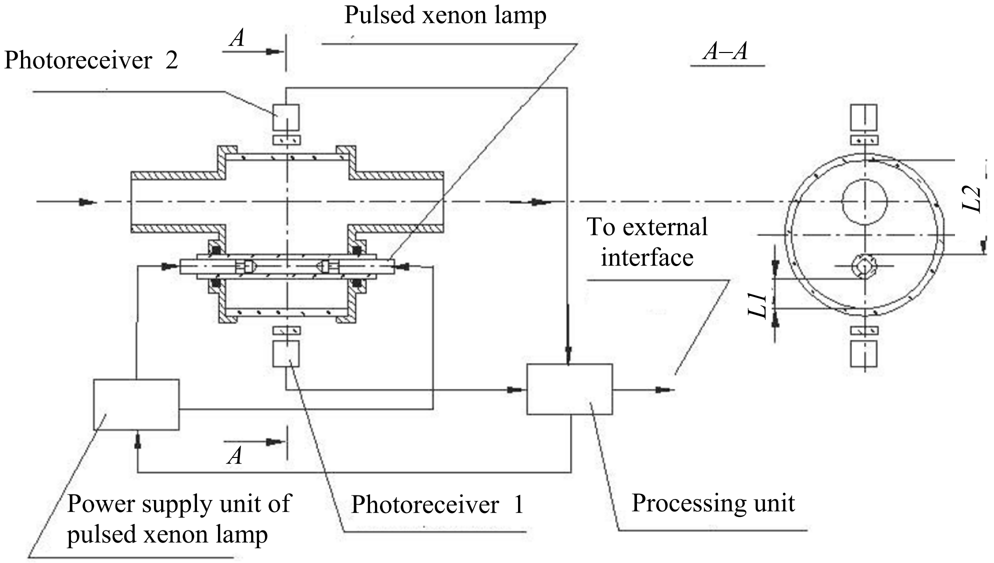

Fig. 9. Schematic diagram of a fast photoelectric sensor.

$$k_{\text{cont}} = \frac{\ln (I_1 - I_2)}{L_2 - L_1}.$$

The $k_{\text{cont}} = k_{\text{w}} + k_{\text{p}}C_{\text{p}}$ is linearly related to and monotonically increases with the concentration of pollutants.

Thus, there is a monotonic dependence of I_1/I_2 on the effective concentrations of pollutants in water. This dependence can form a basis for an algorithm of decision making and functioning of an automated on-line water quality control by desired parameters.

Automated System with a Photoelectric Sensor for On-Line Water Quality Control

Our developed system for water quality control allows acquisition, processing, and analysis of information obtained by means of broad-band spectrometry.

Operation of the Photoelectric Sensor

Before the photoelectric sensor is embedded into the pipeline, a benchmark pollution parameter k_{cont} corresponding to the maximum allowed level of water pollution in a concrete site of the water treatment system is input into the processing unit (PU).

The power supply unit (PSU) operated in the tracking mode keeps the pulsed lamp running with a low pulse frequency, for example, one pulse per 1–10 min (depending on the water flow rate in the pipeline and other process conditions). Every pulse is analyzed by a processing unit, where the current absorptivity is estimated and compared with the benchmark value. When the absorptivity reaches, for example, 90% the benchmark value, the PSU switches to the high-frequency pulse mode, for example, 1–5 Hz (set up during adaptation). This allows the moment when the benchmark absorptivity has been exceeded to be detected with a high degree of precision.

Mathematical processing by special algorithms for special cases, for example, averaging data by several pulses, calculation of an autocorrelation function, calculation of the rate of impairment of the quality of water passing through the sensor, forecast of the trend in water quality, etc., is possible. All required information can be transferred to an external interface or actuators (controlled shutdown valves, vents, etc.).

When the composition of pollutants in water does not vary, their concentrations can be measured directly (in this case, preliminary calibration of the instrument is required). Some additional options are available in the instrument. For example, a couple of additional receivers with another, say, visible, spectral range can be mounted in the instrument. In this case, from the ratio of the absorptivities in different spectral ranges one can determine the type of pollutants (dissolved chemicals or particle suspensions). When photoreceivers are located so that they can detect scattered light of a specific wavelength, turbidity measurements can be made.

Operation of Shut-Off Valves

Two types of shut-off valves are used: normally open and normally, their designs are identical. The

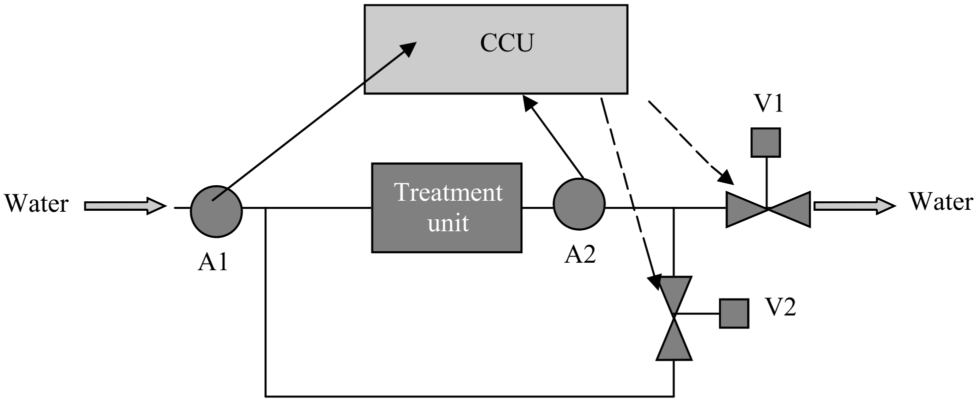

Fig. 10. Schematic process diagram of the water quality control system (on an example of one treatment unit): (A1, A2) water quality analyzers; (V1) normally open valve; and (V2) normally closed valve.

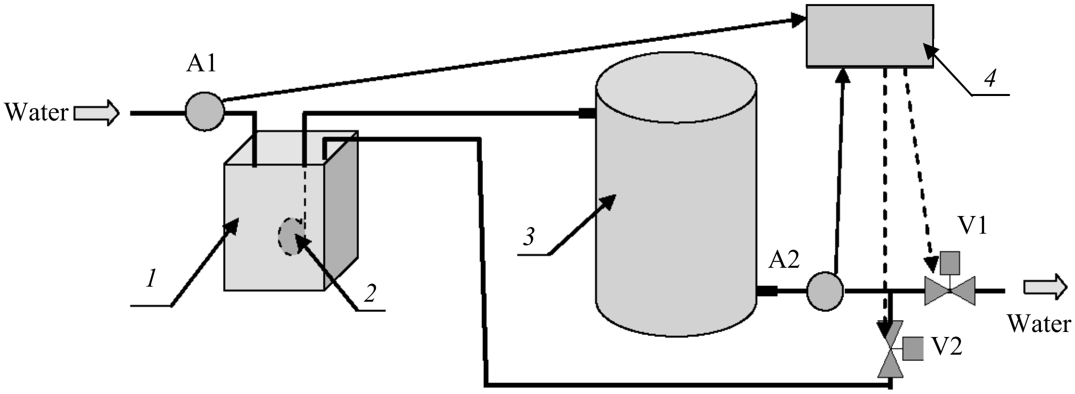

Fig. 11. Schematic process diagram of the water quality and flow control by Scheme 1: (*1*) accumulation tank; (*2*) immersion pump; (*3*) sorption filter of the sorption unit; (*4*) CCU; (A1, A2) water analyzers; (V1) normally open valve; and (V2) normally closed pump.

operation principle of the normally open valve is as follows. When there is current in the solenoid coil, the plunger of the diaphragm bypass orifice is held down by the shutter spring. Due to pressure differential, the principal diaphragm, too, is in the down position, and flow is blocked. Once energized, the solenoid coil raises the plunger, thus opening the bypass orifice. Therewith, the pressures over and under the diaphragm equalize, and the diaphragm goes up and opens the valve. The normally closed valve operates in the same way.

The use of these two solenoid valves allows the flow of treated water, depending on its quality, to be directed to the next treatment block or returned to the previous one for repeated treatment.

Control of Valves and Water Flow

The solenoid valves are controlled from the CCU by signals from analyzers (sensors) of the automated on-line water quality control system. The principle of joint operation of two control systems: spot control of water quality and automated control of treated water flow (to the next treatment unit or to repeated treatment).

On-Line Water Quality Control

Figure 10 shows the schematic process diagram of the automated on-line water quality control system.

The wastewater to be treated passes through the water analyzer A1 which measures pollutant concentrations. Repeated quality control is performed after treatment by means of the analyzer A2. If the water quality fits the benchmark value of the generalized parameter, established for this specific treatment unit, the signal from the CCU directs the water flow via the normally open valve V1 to the next treatment unit. If the water quality does not meet the necessary requirements, the CCU signal closes the normally open valve V1 and opens the normally closed valve V2, and water is returned to the previous unit for repeated treatment.

Provided after repeated treatment water has reached the required quality level, the analyzer A2 sends a corresponding signal to the CCU, the latter initializes V1 and V2 (V1 opens and V2 closes) and the water flow is directed to the next treatment unit.

Two flow and quality control schemes can be realized: at each treatment unit (Scheme 1) or after certain treatment stages (Scheme 2).

Example Scheme 1. The water analyzers and solenoid valves are placed in the sorption unit (Fig. 11). Initial state: the CCU energizes water analyzers and solenoid valves, valve V1 is open, and valve V2 is closed. The wastewater being treated after it has passed the previous unit passes through the quality analyzer A1 and is directed to the accumulation tank *1*.

The immersion pump forces water from the accumulation tank through the sorption filter and further to the quality analyzer A2. If the quality meets requirements, the CCU signal directs the water flow through the normally open valve V1 to the next treatment unit. If the water quality does not meet requirements, the normally open valve V1 is closed, the normally closed valve V2 is opened, and the water flow is directed back to the accumulation tank. After it has repeatedly passed the sorption filter and reaches the necessary requirements, the CCU returns the valves V1 and V2 back to the initial positions (V1 open, V2 closed).

The flow control system can work by this scheme in all treatment units.

CONCLUSIONS

Broad-band spectrometry is proposed as a universal method for on-line control of water quality in different sites of the water treatment process. This method is implemented in a system of on-line water quality control by means of a fast photoelectric sensor.

The photoelectric sensor is built-in into the pipeline, which allows continuous real-time water quality monitoring.

A facility for purification of wastewater from suspensions, equipped with a system of automated on-line control of water quality by desired parameters in different sites of the process. Such treatment systems allow efficient solution of the problem of purification of wastewater containing oil and oil products.

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