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DESIGN OF THE ECOSYSTEM OF MODERN WATER TREATMENT MODULES. (Brief description of the design features and technology of electrochemical water treatment for its subsequent use)

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Abstract

The article examines the features of electrochemical water treatment technology and its subsequent application in medical institutions, biological and microbiological laboratories, art restoration processes, and domestic environments. The operating principles of electrochemical reactors with permeable carbon electrodes and contact elements are presented, enabling water treatment without the use of chemical reagents. The design characteristics of the systems, their operating modes, and the possibilities for adjusting the parameters of treated water, including acidity levels, antibacterial properties, and disinfection processes, are described. Particular attention is given to an integrative complex module for water purification and regeneration that incorporates multistage processes of aeration, sedimentation, ion exchange, filtration, and electrochemical treatment. The use of non-contact monitoring and control systems based on the principles of electromagnetic resonance spectroscopy for real-time monitoring of water parameters is also considered. The article emphasizes the importance of design and configuration solutions in increasing productivity, reducing energy consumption, minimizing equipment dimensions, and achieving a high level of environmental efficiency in intelligent water treatment systems.

Keywords: *Electrochemical water treatment; Electrochemical process; Contact devices; Integrative complex module*

Brief description of the features of electrochemical water treatment technology for its subsequent use in medical facilities, biological and microbiological laboratories; applications of this technology in art restoration processes and domestic environments.

1. Brief presentation of the technology

1.1. The proposed technology represents an electrochemical process of treating water or an aqueous solution passing through the volume of electrodes connected to a direct current power source and separated by a neutral membrane.

1.2. The contacts supplying electrical potential to the electrode volume are manufactured from non-metallic chemically resistant materials and are permeable throughout their entire volume to water and aqueous solutions.

1.3. The electrodes are permeable throughout their entire volume to water and aqueous solutions and are manufactured from non-metallic chemically resistant materials that are chemically compatible with the materials of the electrical contacts.

1.4. The process of treating water or an aqueous solution takes place during its passage through the electrode volume, while the liquid passes through the electrode volume under the influence of gravity in a directed upward flow.

1.5. The electrodes are arranged vertically, with the liquid entering the internal volume of the electrodes at the lower section and exiting at the upper section.

1.6. The duration during which the liquid remains within the internal volume of the electrodes represents the period of exposure, and the duration of this exposure determines the level and depth of influence on the operational characteristics and parameters of the treated water or aqueous solution.

1.7. The device for the proposed type of water and aqueous solution treatment consists of an electrode cell equipped with liquid inlet and outlet systems connected to a source of electrical potential.

1.8. Since this concerns a localized application of the technology, the expected dimensions and capacity of the installation are relatively small; the main distinguishing parameter within the range of such installations is their productivity, which varies from 50 to 250 liters per hour.

1.9. The installations are universal, and their output may include the following types of specially treated water: water with increased acidity; water with reduced acidity; alkaline water for use in various medical technologies and equipment; acidic water for use in various medical technologies and equipment; water purified from bacteria and microorganisms.

1.10. The installations may also be used for the electrochemical disinfection of wastewater from laboratories and surgical complexes in hospitals and research centers.

2. Parameters and properties of water and aqueous solutions treated by the proposed method

2.1. The parameters of water with an increased acidity level are primarily determined by the pH level; for the initial tap water with pH = 7 units, treatment can produce water with pH = 3 units in approximately half of the original volume.

2.2. The parameters of water with a reduced acidity level are also determined by the pH level; when separating the initial water with a neutral pH = 7 units, treatment can produce water with pH = 10 units in approximately half of the original volume.

2.3. In water with an increased acidity level, as a rule, the combination of two types of effects – electrochemical action due to high current density and electrochemical increase of acidity – destroys 100% of all bacteria and microorganisms.

2.4. The acidity level can be adjusted to the required values by changing the electrical current operating modes as well as by modifying the flow rate and productivity of the device.

2.5. The parameters described in sections 2.1–2.4 occur in a device with symmetrical electrodes and two inlets and outlets from the electrode cell.

2.6. A design variant with asymmetrical electrodes is also proposed, in which an increased anode volume – the electrode with a positive electrical potential – results in increased acidity, while an increased cathode volume – the electrode with a negative electrical potential – results in a reduction of acidity throughout the entire volume of the treated water or aqueous solution.

2.7. In the case of symmetrical electrodes, recirculation of one of the flows for repeated treatment is possible if necessary.

3. Examples of applications of water treated using the proposed technology

3.1. Water with a high acidity level is used for sanitary cleaning of hospital premises and for sanitary antibacterial treatment of patients' bodies.

3.2. Water obtained after reverse osmosis treatment and further processed to reduce acidity levels may be used in autoclaves for steam generation without corrosive properties.

3.3. Water with a low acidity level may have a wide range of applications for burn treatment, rinsing procedures, and prevention of sunburn.

3.4. Disinfected wastewater may be discharged into the sewage system.

3.5. Water that has undergone disinfection may be used for various purposes.

4. Device features

4.1. The device housing is manufactured from polymer materials, primarily polyvinyl chloride.

4.2. The entire pipeline structure is made from standard components and may have multiple configurations according to customer requirements.

4.3. The electrodes are manufactured from a composite material – carbon wool.

4.4. The contact devices are manufactured from carbon fabric additionally enriched with carbon.

If necessary, the system may be equipped with non-contact monitoring sensors operating on the principles of electromagnetic resonance spectroscopy.

The author notes the key role played by the books and publications of the well-known specialist Heorhii Babadzhanian in the design and configuration of modules and systems for water purification and regeneration without the use of chemical reagents, while applying the principles of electromagnetic resonance spectroscopy, which make it possible to monitor the parameters of purified and regenerated water without direct contact, online and in real time, thereby ensuring maximum productivity and maximum quality with minimal energy consumption for the process.

In addition, the design approaches developed by Heorhii Babadzhanian significantly increased system productivity, making it possible to substantially reduce module dimensions.

The high precision of monitoring also reduced the likelihood of emergency situations.

The integrative complex module is designed to bring groundwater and water resources of similar quality into compliance with standard requirements.

The productivity of the integrative complex module ranges from 1,500 to 3,000 gallons per day.

The system includes a series of sequential water monitoring and treatment units.

The process of passing through all stages of treatment and monitoring begins with a collector for all incoming water, in which comprehensive active monitoring of all fundamental water parameters is carried out based on the principles of electromagnetic resonance spectroscopy.

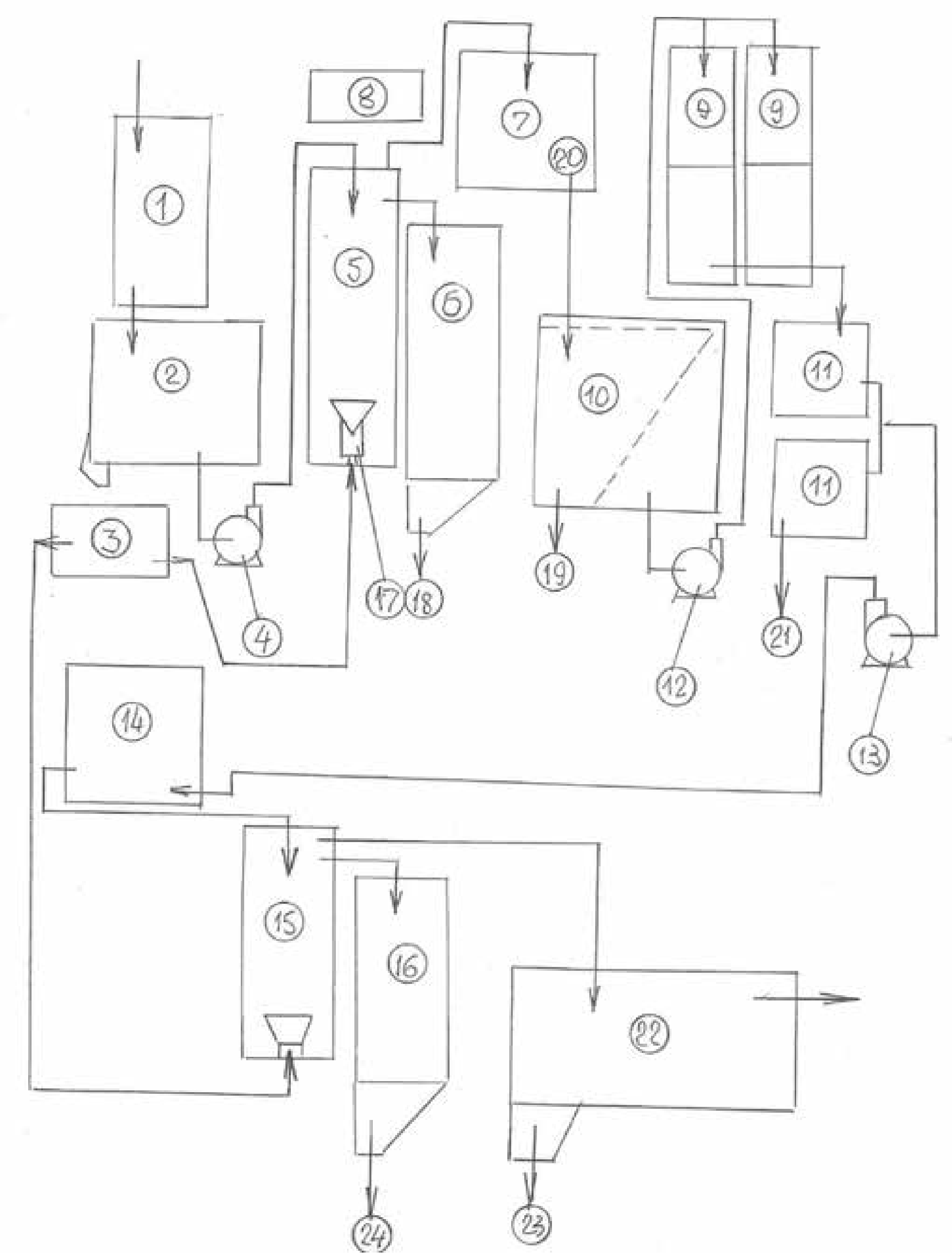
After that, all water enters a tank whose main function is primary sedimentation and separation of the water flow into contaminated water with sediment and water after gravitational sedimentation. This water is then supplied by a pump to a primary aeration column for maximum possible oxygen dissolution in the water, achieved through the action of an aerodynamic vortex foam generator connected to a compressor.

After completion of the first process of aeration and oxygen dissolution in water, part of the water with foamed sediment is removed, while another part is directed to an electrochemical reactor with a multifunctional operating cycle and electrochemical cells equipped with carbon-carbon water-permeable electrodes.

From the electrochemical reactor, the water treated according to the established multifunctional operating cycle is directed into a sedimentation tank, where it is divided into two flows: one flow is directed for disposal after the sedimentation stage, while the second purified flow, processed through the combined multifunctional operating cycle of the electrochemical reactor cells and the contact grid of the sedimentation tank, is directed to ion-exchange purification columns.

After treatment in the ion-exchange purification columns, the purified water is directed to automatic self-cleaning filters, from which, after sediment separation in the filters, it is directed to a second electrochemical reactor with a multifunctional operating cycle. The electrochemical reactor can be reconfigured for several electrochemical water treatment operations without the use of chemical reagents. Such operations include: acidity level adjustment; disinfection; coagulation; flotation; and antibacterial treatment.

Figure 1. *Layout diagram of operational modules in an integrative complex water treatment module at the water supply system inlet*



The water treated in this way is directed to aeration columns for forced oxygen dissolution in water to the level of full saturation, and at the outlet of these columns, sediment and other foamed contaminants are separated from the main flow and disposed of, while the remaining water is supplied to users through a storage reservoir.

The diagram indicates:

1 – a tank into which water enters from the system or collector. This tank contains active online monitoring systems for contamination levels in water based on the principles of electromagnetic resonance spectroscopy (an invention of the project authors).

2 – a primary sedimentation tank with an outlet connected to pump 4 and equipped with a sediment discharge line.

3 – a compressor connected to aerodynamic foam generators in columns for separating sediment fractions and other contaminants.

4 – a centrifugal pump with all necessary infrastructure.

5 – a column for aeration and oxygen dissolution in water and for lifting foamed

contaminants and organic matter to the upper section of the column.

6 – a column for separating foamed sediment and contaminants from the water mass.

7 – an electrochemical reactor with a multifunctional operating cycle. The electrochemical reactor can be reconfigured for several electrochemical water treatment operations without the use of chemical reagents. Such operations include: acidity level adjustment; disinfection; coagulation; flotation; and antibacterial treatment.

8 – a non-contact water quality monitoring system controlled by a dedicated processor connected to sensor modules installed at corresponding pipeline sections and operating according to the principles of electromagnetic resonance spectroscopy.

9 – ion-exchange treatment columns with a sectional structure. Depending on productivity requirements, a column may include one, two, or three sections. Such a structure allows one column to contain three ion-exchange materials, including the natural ion-exchange material zeolite.

10 – a sedimentation tank receiving discharge from the electrochemical reactor and from which water separated from sediment is supplied by a pump to the inlet of the ion-exchange treatment columns – 9.

11 – automatic self-cleaning mechanical filters, which may be replaced with automatic membrane filters.

12 – a pump supplying purified water from sedimentation tank 10 to the inlets of ion-exchange treatment columns 9.

13 – a pump supplying purified filtered water from filters 11 to the second electrochemical reactor with a multifunctional cycle.

14 – an electrochemical reactor with a multifunctional operating cycle. The electrochemical reactor can be reconfigured for several electrochemical water treatment operations without the use of chemical reagents. Such operations include: acidity level adjustment; disinfection; coagulation; flotation; and antibacterial treatment.

15 – a column for aeration and oxygen dissolution in water and for lifting foamed contaminants and organic matter to the upper section of the column; an aerodynamic vortex foam generator is installed in the lower part of the column.

16 – a column for separating foamed sediment and contaminants from the water mass.

17 – an innovative aerodynamic vortex foam generator with its inlet connected to the compressor outlet.

18 – the outlet and discharge line from column 6, which is used as a column for separating foamed sediment and contaminants from the water mass.

19 – a discharge line for removing sediment from sedimentation tank 10.

20 – a discharge pipeline for water treated in the electrochemical reactor into sedimentation tank 10. Water in the electrochemical reactor may undergo several treatment operations without the use of chemical reagents. Such operations include: acidity level adjustment; disinfection; coagulation; flotation; and antibacterial treatment.

21 – a reserve sediment discharge line from automatic mechanical filters or their equivalents – membrane filters.

22 – a final storage tank for treated water before delivery for consumption.

23 – a reserve discharge line for accumulated sediment and contaminants from the storage tank.

24 – a discharge line from column 16 for separating foamed sediment and contaminants from the water mass.

In the specified configuration, all included modules are multifunctional and can be adjusted to operate with several types of source water supplied to the input of the integrative complex module.

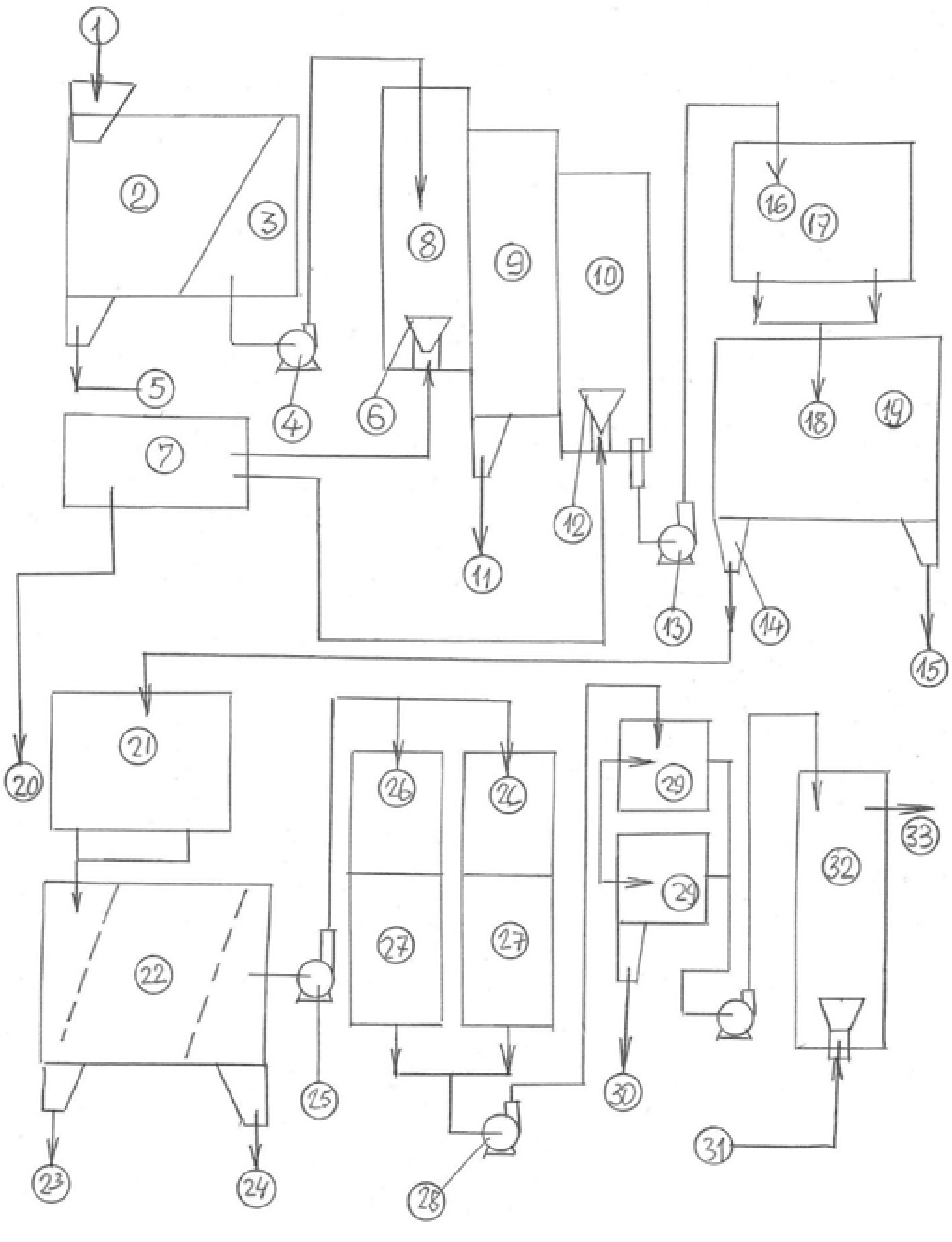
For the monitoring and control of electrochemical reactors within the integrative complex module, its structure includes a control and management system functionally connected to non-contact electromagnetic resonance sensor modules operating according to the principles of electromagnetic resonance spectroscopy.

The specified system can operate in a fully autonomous automatic cycle with complete control over the results and quality of water treatment at all stages of processing.

The specified system possesses a 100 percent level of flexibility and, during operation and configuration, can modify the sequence and operational characteristics depending on requirements and the technical specifications of the integrated components and systems.

All of the stated advantages have arisen specifically due to the comprehensive implementation of the design and configuration approaches developed by Heorhii Babadzhanian and make it possible, at minimal cost, to ensure maximum compliance with environmental standards while maintaining high performance indicators of the ecosystem and infrastructure of intelligent water treatment equipment.

Figure 2. *Integrative complex module for water regeneration with preparation for recirculation. The entire regeneration process is carried out without the use of chemical reagents*



The integrative complex multifunctional process for the regeneration of water used at a single facility includes the following systems:

Input sedimentation without additional treatment.

Foam treatment with separation of sediment fractions and organic contaminants.

Separation of the foamed contaminant complex from contamination-free liquid.

Repeated aeration of separated water with oxygen dissolution to the level of full saturation.

Comprehensive water treatment in an electrochemical reactor according to a multifunctional scheme, including acidity level adjustment, disinfection, saturation with coagulants or flocculants, and restoration of water flows to a common acidity level.

Sedimentation in the discharge water flow containing coagulants or flocculants.

Repeated multifunctional treatment of the water flow from the sedimentation tank with coagulants or flocculants according to the following final scheme: acidity level adjustment, disinfection, and restoration of the entire treated water flow to a common acidity level.

Final sedimentation of all water treated in the second electrochemical reactor.

Treatment in ion-exchange columns, including sections with natural granular zeolite instead of synthetic ion-exchange resin.

Treatment in automated self-cleaning mechanical filters or membrane filters.

Final aeration using aerodynamic vortex foam generation with oxygen dissolution to the level of complete saturation.

The diagram shows:

1 – an input sedimentation tank for formed sediment with functions for removing accumulated sediment and directing sediment-free water to the next treatment stage.

2 – a sedimentation section in tank 1.

3 – a concentration section for sediment-free water in tank 1.

4 – a pump for transferring sediment-free water to subsequent treatment stages.

5 – a system for removing water containing formed sediment.

6 – an aerodynamic vortex foam generator.

7 – a compressor operating with three aerodynamic vortex foam generators.

8 – a column for vortex foaming of water without formed sediment.

9 – a column into which foam from the upper section of column 8 is discharged, intended for aerodynamic vortex foaming of water without formed sediment.

10 – a column for vortex foaming and establishing the required aeration level and saturation of treated water with dissolved oxygen up to complete saturation.

11 – a contaminant discharge outlet from column 9, into which foam from the upper section of column 8 intended for aerodynamic vortex foaming of sediment-free water is discharged.

12 – an intermediate aerodynamic vortex foam generator.

13 – a pump for supplying water, after treatment in column 10 and with maximum air content and dissolved oxygen saturation, to the electrochemical cells of the first electrochemical reactor in the liquid flow sequence.

14 – a discharge pipeline for purified water after sedimentation and comprehensive treatment in the first electrochemical reactor in the liquid flow sequence.

15 – a contaminant discharge outlet from the sedimentation tank installed after the electrochemical reactor.

16 – water inlet into the electrochemical reactor cells after aeration and oxygen dissolution to the level of complete saturation.

17 – the electrochemical reactor housing.

18 – a water outlet from the interelectrode space of the electrochemical reactor cells after completion of the treatment cycle.

19 – a comprehensive sedimentation tank.

20 – an outlet from compressor 7 to the inlet of the final aerodynamic vortex foam generation system.

21 – a multifunctional electrochemical reactor for comprehensive final water treatment according to a multifunctional scheme, including acidity level adjustment, disinfection, and restoration of the entire treated water flow to a specified overall acidity level.

22 – a comprehensive sedimentation tank.

23 – a discharge outlet for contaminated liquid.

24 – a reserve discharge outlet for water from the purified water section of the sedimentation tank.

25 – a pump for supplying water from the final section of the sedimentation tank to ion-exchange column segments.

26 – upper sections of ion-exchange columns in which granular zeolite is used as the ion-exchange material.

27 – lower sections of ion-exchange treatment columns containing ion-exchange resin.

28 – a pump for transferring water after purification in ion-exchange columns to automated self-cleaning mechanical filters or membrane filters.

29 – a system of automated self-cleaning mechanical filters with a pump for supplying filtered water to the final aeration and oxygen dissolution column up to complete saturation.

30 – a sediment discharge outlet from the automated self-cleaning filters.

31 – a final aerodynamic vortex foam generator.

32 – a column for the final stage of aeration and oxygen dissolution in water up to complete saturation.

33 – a line for supplying regenerated water for recirculation.

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