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**Title:**

# Classification of Water Treatment Systems

**Subtitle:**

## Classification of systems for the integrated treatment of water and aqueous solutions

## Integrated industrial systems for the treatment of water and aqueous solutions; basic industrial modules

**Keywords:**

Integrated water treatment systems; integrated treatment systems for aqueous solutions; basic industrial modules; capacity of a basic industrial module; operating throughput of a single basic module; minimum capacity of one basic industrial module; system as a complex of modules.

**Abstract:**

For the infrastructure of a smart home that must supply water at the required level of consumption in accordance with current quality standards, the following sequence of treatment and regeneration has been established on the basis of existing experience with the electrochemical treatment of water.

For water entering the smart home's plumbing system:

- For water from line sources — an inlet treatment using aerodynamic foam generators that separate organic contaminants and simultaneously dissolve atmospheric oxygen in the water, raising the dissolved-oxygen saturation to 96% (data from tests carried out in leading laboratories).
- For free-standing smart homes whose water is drawn from artesian wells, the inlet treatment is also carried out using electrochemical cells within an electrochemical reactor, in which the following operations may be performed:
- Desalination by accelerated electrolytic deposition of salt onto a moving cathode made of carbon-carbon composite fabric.
- Correction of pH to a neutral level.
- Saturation of the water with coagulant for subsequent sedimentation and separation of the sludge from the clean water.
- Aeration of the water by means of aerodynamic foam generators.

Where necessary, disinfection of the water streams by sequentially shifting the pH to acidic and then raising it back to neutral.

For used water, the same electrochemical treatment system makes it possible to clean the water of the contaminants introduced during use, and thereafter to activate the cleanest portion of the water stream for subsequent recirculation and to use the remaining water for irrigation.

**Contents:**

# Classification of Systems for the Integrated Treatment of Water and Aqueous Solutions

Integrated industrial systems for the treatment of water and aqueous solutions have a modular structure.

The minimum capacity of one basic industrial module with a single two-section column for ion-exchange treatment is 500 litres per hour.

The operating throughput of one basic module with two two-section columns for ion-exchange treatment is 1,000 litres per hour.

The minimum capacity of one basic industrial module with a single three-section column for ion-exchange treatment is 750 litres per hour.

The operating throughput of one basic module with two three-section columns for ion-exchange treatment is 1,500 litres per hour.

Practice has shown that the most efficient systems for treating and recirculating process water directly within a production line are the following:

- A system — a complex of modules — with a throughput of 1,000 litres per hour.
- A system — a complex of modules — with a throughput of 1,500 litres per hour.
- A system — a complex of modules — with a throughput of 2,000 litres per hour.
- A system — a complex of modules — with a throughput of 2,500 litres per hour.
- A system — a complex of modules — with a throughput of 3,000 litres per hour.

For all the systems listed above, the ion-exchange columns are made with two sections.

When it is necessary to increase the throughput of the modular complex, three-section ion-exchange columns are used.

In that case the throughput of the systems for treating and recirculating process water directly in the production line corresponds to the following values:

- Modular system with a throughput of 1,500 litres per hour.
- Modular system with a throughput of 2,000 litres per hour.
- Modular system with a throughput of 2,500 litres per hour.
- Modular system with a throughput of 3,000 litres per hour.
- Modular system with a throughput of 3,500 litres per hour.

As an example, the author describes a modular complex for purifying radioactive water.

An installation for the purification and regeneration of process water used in the cooling systems of a nuclear reactor and the associated process equipment was ordered by the company operating the reactor, with mandatory oversight and scientific supervision by the university and, personally, by the developer of the special algae OZOLA, which possess the property of accumulating radioactive materials.

The installation was ordered from a company — Industrial Ecology — that had been created at the Technological Incubator and that had demonstrated the effectiveness of its integrated core technology for cleaning and regenerating process water, including water containing radioactive isotopes and ions of radioactive isotopes of heavy metals.

The order specified an installation throughput of 500 litres per hour.

In accordance with the technical specification and the original technical requirements, the installation comprised the following modules:

- A fine-filtration module.
- An inlet-filtration module with additional filtering elements made of carbon-carbon composite fabric, packed with carbon-carbon composite wadding.
- A sedimentation module.
- An electrochemical-reactor module with electrochemical cells whose electrodes are made of carbon-carbon composite fabric.
- A module — an ion-exchange section based on zeolite.
- A module — an ion-exchange section based on granules of dried OZOLA algae.
- A first-stage final-filtration module with automatic cleaning.
- A second-stage final-filtration module with automatic cleaning.
- An automatic control and monitoring module.

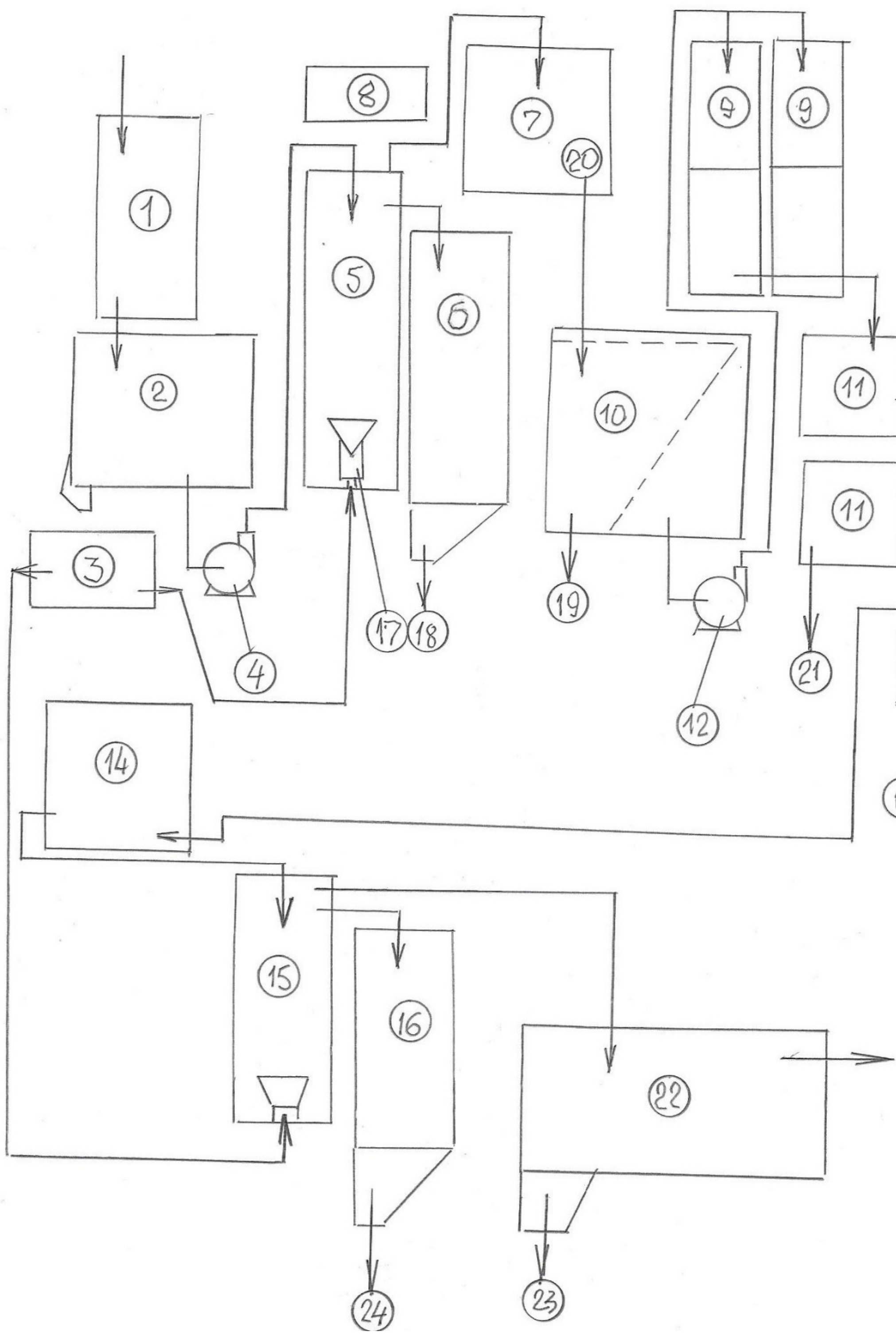



*Figure 1. Layout of the working modules in the integrated water-treatment module installed at the inlet of the water-supply system.*

The integrated module is designed to bring groundwater and water resources of similar quality up to the level required by the relevant standards.

The throughput of the integrated module ranges from 1,500 to 3,000 gallons per day.

The system contains a series of sequential blocks for monitoring and treating the water.

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

After that, all the water enters a tank whose main task is primary sedimentation and the separation of the water stream into water containing contaminants and sediment, and water freed of sediment by gravitational settling. The latter is then pumped into the primary column for aeration and the maximum possible dissolution of oxygen in the water, achieved by the action of an aerodynamic vortex foam generator coupled to a compressor.

After the first stage of aeration and oxygen dissolution is complete, part of the water together with the foamed sediment is removed, and part is sent to an electrochemical reactor with a multifunctional operating cycle and with electrochemical cells fitted with water-permeable carbon-carbon electrodes.

From the electrochemical reactor, water treated in accordance with the prescribed multifunctional operating cycle is directed to a sedimentation tank where it is divided into two streams: one is sent for disposal after the sedimentation section, and the second — purified in the combined multifunctional operating cycle of the electrochemical cells of the reactor and the contact grid of the sedimentation tank — is directed to the ion-exchange purification columns.

After treatment in the ion-exchange purification columns, the cleaned water is directed to automatic self-cleaning filters, from which, after the sediment has been separated out, it is directed to the second electrochemical reactor in the process flow, also with a multifunctional operating cycle.

The electrochemical reactor can be reconfigured for several reagent-free electrochemical water-treatment operations, including: pH correction, disinfection, coagulation, flotation, and antibacterial treatment.

The water treated in this way is directed to the aeration columns, where oxygen is forced into the water up to full saturation. At the outlet of these columns the sediment and other foamed contaminants are separated from the main stream and disposed of, while the remaining water is sent via a storage tank to the users.

**Key to Figure 1.**

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

2 — Primary sedimentation tank with an outlet to pump-4 and a drain line for the sediment.

3 — Compressor connected to the aerodynamic foam generators in the columns used for separating sediment fractions and other contaminants.

4 — Centrifugal pump with all the necessary auxiliary equipment.

5 — Column for aeration and the dissolution of oxygen in water, and for lifting foamed contaminants and organics to the upper part of the column.

6 — Column for separating foamed sediment and contaminants from the bulk of the water.

7 — Electrochemical reactor with a multifunctional operating cycle. The reactor can be reconfigured for several reagent-free electrochemical water-treatment operations: pH correction, disinfection, coagulation, flotation, and antibacterial treatment.

8 — Non-contact water-quality monitoring system, controlled by a dedicated processor connected to sensor modules installed at the appropriate sections of pipework. The sensors operate on the principles of electromagnetic resonance spectroscopy.

9 — Ion-exchange treatment columns of sectional construction. Depending on the throughput, the column may contain one, two or three sections. This structure makes it possible to hold three ion-exchange materials within a single column, including the natural ion-exchange material zeolite.

10 — Sedimentation tank which receives the drainage from the electrochemical reactor and from which the water — having been separated from the sediment — is pumped to the inlet of the ion-exchange treatment columns (item 9).

11 — Automatic self-cleaning mechanical filters, which can also be replaced by automatic membrane filters.

12 — Pump that feeds the cleaned water from sedimentation tank 10 to the inlets of ion-exchange treatment columns 9.

13 — Pump that feeds the cleaned, filtered water from filters 11 to the second electrochemical reactor with a multifunctional operating cycle.

14 — Electrochemical reactor with a multifunctional operating cycle. The reactor can be reconfigured for several reagent-free electrochemical operations, including pH correction, disinfection, coagulation, flotation, and antibacterial treatment.

15 — Column for aeration and dissolution of oxygen in the water and for lifting foamed contaminants and organics to the upper part of the column; an aerodynamic vortex foam generator is installed at the bottom of the column.

16 — Column for separating foamed sediment and contaminants from the bulk of the water.

17 — Innovative aerodynamic vortex foam generator, whose inlet is connected to the outlet of the compressor.

18 — Outlet and drain from column 6, which is used to separate foamed sediment and contaminants from the bulk of the water.

19 — Drain line for sediment from sedimentation tank 10.

20 — Drain line for water treated in the electrochemical reactor and discharged into sedimentation tank 10. In the electrochemical reactor the water may be processed through several reagent-free operations: pH correction, disinfection, coagulation, flotation, and antibacterial treatment.

21 — Backup sediment drain from the automatic mechanical filters or their equivalents (membrane filters).

22 — Final storage tank for treated water prior to delivery for consumption.

23 — Backup drain for sediment and contaminants accumulating in the storage tank.

24 — Drain from column 16, used for separating foamed sediment and contaminants from the bulk of the water.

In the configuration described, all included modules are multifunctional and can be adjusted to handle several types of feed water supplied to the inlet of the integrated module.

The integrated module is fitted with a control and monitoring system for the electrochemical reactors, functionally linked to non-contact electromagnetic resonance sensor modules operating on the principles of electromagnetic resonance spectroscopy.

This system can operate in a fully autonomous, automatic cycle with full monitoring of the results and the quality of treatment at every stage.

The system offers 100% flexibility: during operation and tuning it can change the order and the specifics of its work according to need and to the technical characteristics of the elements and systems involved.

**Answers to questions on technologies for the treatment of industrial wastewater**

**Question 1.**

What is the relationship between the proposed methods? If such a relationship exists, how is it expressed?

An integrated technology for treating industrial wastewater is proposed, consisting of a series of sequential but mutually independent operations.

More precisely, all the stages of water treatment can be viewed as variants of sequential action upon the water, each of which has its own physical and chemical principles of operation.

We propose an integrated technology that can be implemented through self-contained, autonomous, standardised process modules, in the following arrangement:

- A module for the preliminary accumulation of the liquid to be treated. This module is not fundamentally novel, but if a number of modifying elements drawn from the author's portfolio of innovations are added to it, an unusual yet much-needed market result can be obtained.
- A preliminary mechanical-filtration module with ion-exchange treatment elements. This is an original technology.

The proposed module provides a solution to many of the related problems involved in treating water after it has been used in a process and contaminated by the by-products and waste of that process. The main purpose of this module is mechanical filtration combined with concurrent treatment by various natural and composite materials. The construction is cartridge-based, providing maximum flexibility of layout.

- An aerodynamic turbo-flotation module. The module is an original technology. It uses aerodynamic foam generators that make it possible to form foam while the treated liquid is in constant motion. The main distinctive feature of the module is the high speed of foam formation, which makes it possible to foam organic impurities in the moving liquid stream and subsequently to separate them efficiently from the main volume.
- An electrolytic metal-extraction module, using the method of high-speed electrolytic metallisation. The same module can also be configured as:
- A disinfection module.
- A pH-correction module.
- An alkalinity-correction module.
- An electrochemical-coagulation module. This module can likewise have several fundamentally different design variants.

All configurations of this module constitute original technology.

A final mechanical-filtration module with ion-exchange and biological-sorption elements. This is an original technology.

A module — an ion-exchange and biological-sorption column.

A module for accumulating treated liquid prior to its disposal or onward use.

**Question 2.**

In which industries are which water-treatment processes currently in use?

Currently, in the various industries that use water for technological purposes, the following methods are employed for cleaning water contaminated by the products and waste of those processes:

- Chemical-reagent treatment. Several modifications of this method exist, along with combinations with other technologies. This method and its modifications are the most widespread, occupying more than 70% of the water-treatment market.
- Reagent-free water treatment and purification. Several basic modifications of this method exist, differing in their range of capabilities and characteristics. These methods cover less than 20% of the water-treatment market.
- Various combined methods, generally assembled from the first two together with additional technological techniques dictated by the local conditions of the users. These methods cover about 10% of the market and tend to expand their reach.

**Question 3.**

What problems do users of water-treatment technology face today, and what solutions are currently available to overcome them?

As of today, users of water-treatment technologies face a whole range of problems that prevent the efficiency of auxiliary water-treatment operations from rising to the level of efficiency of the core process operations. The principal problems include:

- A constant limitation of the water resources available for use in industrial processes.
- A continuous deterioration in the quality of the natural water resources that can be used in industrial processes.
- A continuous rise in the cost of water resources.
- Continuously tightening standards for water that can be discharged into the sewer system, which increases the cost of treating wastewater.
- Continuously rising requirements for the parameters of water used in industrial processes.
- As new processes are developed and existing ones improved, the constant appearance of new, previously unused materials — both synthetic and organic — which requires the constant modernisation of water-treatment facilities or a very broad range of capabilities in those facilities. This involves a significant increase in cost both for the equipment and for the treatment process itself.
- The existence of large numbers of production facilities operating with traditional technology whose equipment has reached the end of its service life, and whose replacement requires significant expenditure or is altogether impossible.

**Question 4.**

Can today's problems be overcome on the basis of, and with the help of, existing technologies?

The water-treatment and water-preparation problems identified today cannot be solved on the basis of known methods and technologies. The solution must be integrated, because a partial solution does not satisfy any modern production facility. For this reason, the application of one method, or of a combination of others, fails to address all of the new requirements that have arisen and continue to arise.

**Question 5.**

Which water-treatment technologies have been introduced into industry over the past 10 years? What problems do these technologies solve and overcome?

Over the past 10 years, no entirely new directions have appeared in water-treatment technology. The new developments have essentially concerned the use of new materials within the basic variants of the water-treatment technologies formulated in earlier years. The component base has of course advanced, but no fundamentally new integrated technologies have emerged.

All improvements have solved local problems while the situation in which no integrated solution existed remained unchanged.

The fundamental problems have persisted in every variant; the main, unchanging ones are:

- The presence of significant quantities of waste requiring disposal.
- The need for large quantities of water-treatment materials.
- The need for significant production space for water treatment.
- The need for significant energy expenditure for water treatment.

**Question 6.**

At what stage of development are the new ideas proposed by the author of this publication? How quickly can they be brought to industrial prototypes? Are there any technological difficulties in building this equipment? What will the commercial product based on these new technologies look like?

Implementing the new ideas in water treatment does not require the development of new materials and technologies. For that reason, the design and manufacture of pilot prototypes does not take much time; for the various modules this period ranges from four to eight months. The prototypes can be manufactured at any medium-scale engineering enterprise.

**Question 7.**

What will the proposed technology cost the user? What is the structure of that cost? Which of the proposed technical solutions will be most attractive to potential users?

The user cost of the proposed technologies will be based on the model of delivery and marketing chosen by the consumer from among those offered. It is generally accepted that a modular approach makes it possible to offer the consumer flexible payment terms tailored to the conditions prevailing at the time of the offer.

The character of the cost and the price structure for the modules rest on the following base points:

- A modular structure increases the serial-production volume of the product.
- A modular structure makes it possible to manufacture the modules in different countries with differing levels of engineering culture.
- A modular structure makes it possible to integrate the modules into process complexes with differing degrees of integration and differing levels of technical sophistication.
- With a modular structure, expenditure on foundations and other utilities is significantly reduced.
- A modular structure makes it possible to achieve a high degree of standardisation of design and technological solutions, which improves the quality of manufacture and installation as well as the cost of producing spare parts.

**Question 8.**

What problems does the proposed technology not solve? What new problems may arise from the development of existing technologies that the proposed technologies are not designed to solve? For how long can the proposed technologies be expected to remain in confident demand among potential consumers, taking into account current development trends in technologies that use water for industrial purposes?

The proposed technology is integrated and is in practice capable of solving all the water-treatment problems known today. There are many subjective reasons why a potential consumer of the technology may decline to implement a process solution to its problems and instead look for reasons to argue that purifying water at its facility is impossible. In such cases the problems are subjective, and solving them against the consumer's will is organisationally difficult.

The proposed solutions are technologically flexible enough to adapt to any variant of change in the underlying production technology.

**Question 9.**

What is the position of current regulatory standards and other regulatory documents in relation to the proposed technology? How does the proposed technology ensure compliance with the requirements of those standards?

The proposed technology is fully adapted to the requirements of current environmental standards. This applies first and foremost to the final concentrations of metals in the treated water; the absence of toxic waste; the possibility of returning the cleaned water to the production process; and the possibility of reducing the volume of discharged effluent.

**Question 10.**

In the view of the technology developer, what might cause a consumer of the technology to decide to keep its existing technology and not adopt the proposed new one?

There can be a number of such reasons:

- The existing technology has no significant problems with the quality of purification.
- The cost of water in the user's region is low, or water expenses are subsidised by the government.
- The production has no commercial future in its current location, and the operation is planned to be relocated to developing countries.
- The process equipment is laid out very densely and does not allow the installation of new equipment without rebuilding the facility.
- The cost of purification by the proposed technology is higher than by the existing one.

**Question 11.**

For each of the proposed technical ideas, what is required to verify it experimentally for conceptual viability and commercial demand?

For the electrolytic metal-extraction technology it is appropriate to verify experimentally the efficiency of the extraction process and the initial and final concentrations of metal in the water.

For the aerodynamic-foaming technology it is appropriate to verify experimentally the efficiency of the process and the initial and final concentrations of organic contaminants in the water.

**Question 12.**

Patent and licensing situation for the proposed technologies; the patentability of the proposed technological methods.

For the proposed water-treatment methods, the preliminary analysis and patent search have identified the following topics for patent applications:

- A modular complex for the deep treatment of water and aqueous solutions, and the associated method of use.
- A method for the integrated treatment of water, and the process modules for implementing that method.
- A method for the electrolytic extraction of metals from a stream of water or aqueous solution, and the electrode cells for implementing that method.
- A method for the aerodynamic foaming of water in its continuously flowing stream, and the foam generator for implementing that method.
- An integrated method of filtration combined with ion-exchange treatment and biological sorption.
- An electrode cell for electrocoagulation with coaxial electrodes.
- An electrode cell for electrocoagulation with a continuously moving belt cathode.
- An electrode cell for pH or alkalinity correction with blocks of polarisable, soluble electrodes.
- An electrode cell for pH or alkalinity correction with bulk-porous electrodes.
- An electrode cell for pH or alkalinity correction with continuously moving belt electrodes.
- An electrode cell for electrochemical disinfection, and electrode cells for implementing that method.

For each patent application, prototypes and analogues have been identified from among the inventions of the author of the proposed new methods. The preliminary patent search and structural analysis have established the full patentability of the technical solutions listed above.

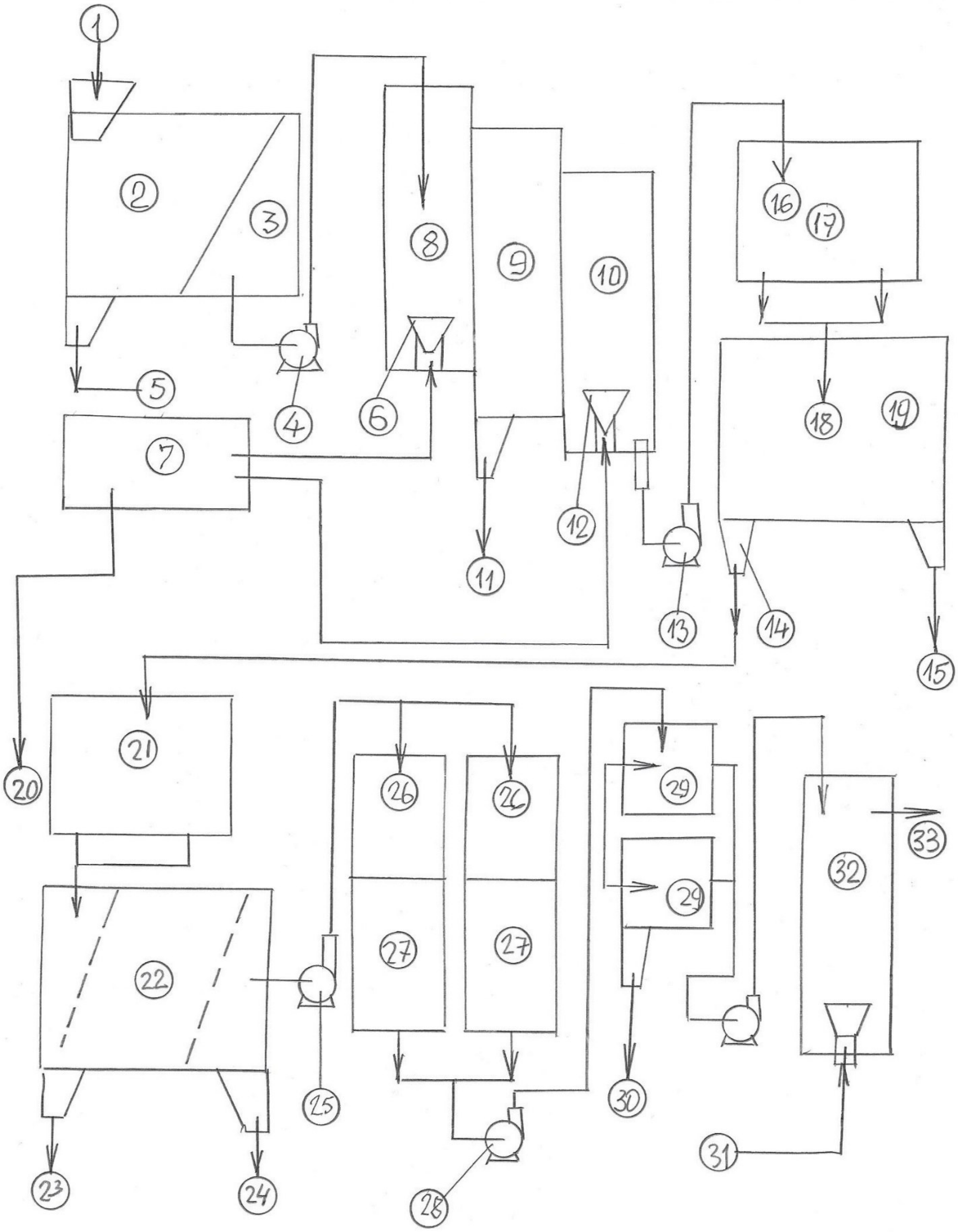


*Figure 2. Integrated module for water regeneration with preparation for recirculation.*

**Integrated module for water regeneration with preparation for recirculation**

The entire regeneration process is carried out without the use of chemical reagents.

The integrated, multifunctional process for regenerating water used at a single site comprises the following systems:

- Inlet sedimentation, without additional treatment.
- Foam treatment with separation of sediment and organic-contaminant fractions.
- Separation of the foamed contaminant complex from the contaminant-free liquid.
- Repeated aeration of the separated water with dissolution of oxygen to the level of full saturation.
- Integrated water treatment in the electrochemical reactor according to a multifunctional scheme — pH correction, disinfection, saturation with coagulants or flocculants, and return of the water streams to a common pH level.
- Sedimentation in the discharge stream of water containing coagulants or flocculants.
- Repeated multifunctional treatment of the water stream from the sedimentation tank containing coagulant or flocculant, according to the following final scheme: pH correction, disinfection, and return of the entire treated water stream to a common pH level.
- Final sedimentation of all water treated in the second electrochemical reactor.
- Treatment in ion-exchange columns, including sections with natural granular zeolite in place of synthetic ion-exchange resin.
- Treatment in automated self-cleaning mechanical or membrane filters.
- Final aeration by means of aerodynamic vortex foam generation, with dissolution of oxygen to the level of full saturation.

**Key to Figure 2.**

1 — Inlet sedimentation tank for accumulated sediment, with functions for removing the settled sediment and directing the sediment-free water to the next stage of treatment.

2 — Sedimentation section within tank 1.

3 — Section in tank 1 holding the water that has been freed of settled sediment.

4 — Pump that conveys the sediment-free water to subsequent stages of treatment.

5 — System for removing water that contains settled sediment.

6 — Aerodynamic vortex foam generator.

7 — Compressor operating with three aerodynamic vortex foam generators.

8 — Column for vortex foaming of the sediment-free water.

9 — Column into which the foam from the upper part of column 8 (the vortex aerodynamic foaming column for sediment-free water) is discharged.

10 — Column for vortex foaming and for producing the required level of aeration and saturation of the treated water with dissolved oxygen up to full saturation.

11 — Drain for contaminants from column 9, which receives the foam discharged from the upper part of column 8.

12 — Intermediate aerodynamic vortex foam generator.

13 — Pump that feeds water — after treatment in column 10 with maximum air content and dissolved oxygen up to full saturation — to the electrochemical cells of the first electrochemical reactor in the flow.

14 — Drain line for the purified water leaving sedimentation after integrated treatment in the first electrochemical reactor in the flow.

15 — Drain for contaminants from the sedimentation tank installed after the electrochemical reactor.

16 — Water inlet to the electrochemical cells of the electrochemical reactor, after aeration and dissolution of oxygen to full saturation.

17 — Body of the electrochemical reactor.

18 — Drain for water from the inter-electrode space of the electrochemical-reactor cells after a full treatment cycle.

19 — Integrated sedimentation tank.

20 — Outlet from compressor 7 to the inlet of the final aerodynamic vortex foam-generator system.

21 — Multifunctional electrochemical reactor for the integrated final treatment of water according to the multifunctional scheme: pH correction, disinfection, and return of the entire treated water stream to the specified common pH level.

22 — Integrated sedimentation tank.

23 — Drain for contaminated liquid.

24 — Backup water drain from the section of the sedimentation tank for clean water.

25 — Pump that feeds water from the final section of the sedimentation tank to the segments of the ion-exchange columns.

26 — Upper sections of the ion-exchange columns, in which granular zeolite is used as the ion-exchange material.

27 — Lower sections of the ion-exchange columns, which contain ion-exchange resin.

28 — Pump for transferring water — after purification in the ion-exchange columns — into the automated self-cleaning mechanical or membrane filters.

29 — System of automated self-cleaning mechanical filters together with the pump that feeds the filtered water into the column for final aeration and dissolution of oxygen up to full saturation.

30 — Sediment drain from the automated self-cleaning filters.

31 — Final aerodynamic vortex foam generator.

32 — Column for the final stage of aeration and dissolution of oxygen in the water up to full saturation.

33 — Line for delivering the regenerated water to recirculation.

**Autonomous integrated modular system for the inlet treatment of mains water and for the regeneration of used water with recirculation on the residential lot of a home:**

- For washing streets and pavements.
- For use at industrial facilities whose required water standards match the parameters of the water produced after regeneration.

A water-treatment system is proposed, consisting of two main parts: a system for the inlet treatment of water before use in the home, and a system for regenerating used water for its reuse in various infrastructure scenarios.

Both systems include online non-contact water-quality monitoring devices at every stage of treatment, at the inlets and at the outlets.

These active quality-monitoring devices are based on the principles and methods of electromagnetic impedance and resonance spectroscopy (a company technology under licence from the author of this publication).

The inlet-water-treatment system consists of an automatic mechanical filter with automatic cleaning of the filter elements;

of a device for in-line aeration and dissolution of oxygen in the water up to full saturation (a company technology under licence from the author of this publication);

and of an electrochemical reactor for pH correction in the water in two directions (a company technology under licence from the author of this publication).

The equipment set for this part of the system also includes a compressor and multi-position foam generators designed to turn bathtubs into Jacuzzis while reducing water consumption (a company technology under licence from the author of this publication).

The system for regenerating used water consists of a used-water collector (settling tank) equipped with foam generators that produce an aerodynamic flotation effect, which assists in the effective separation of organic waste from the water (a company technology under licence from the author of this publication).

After organic contaminants have been separated, the used water is sent to the integrated electrochemical reactor, in which pH correction in two directions is carried out together with simultaneous disinfection (a company technology under licence from the author of this publication).

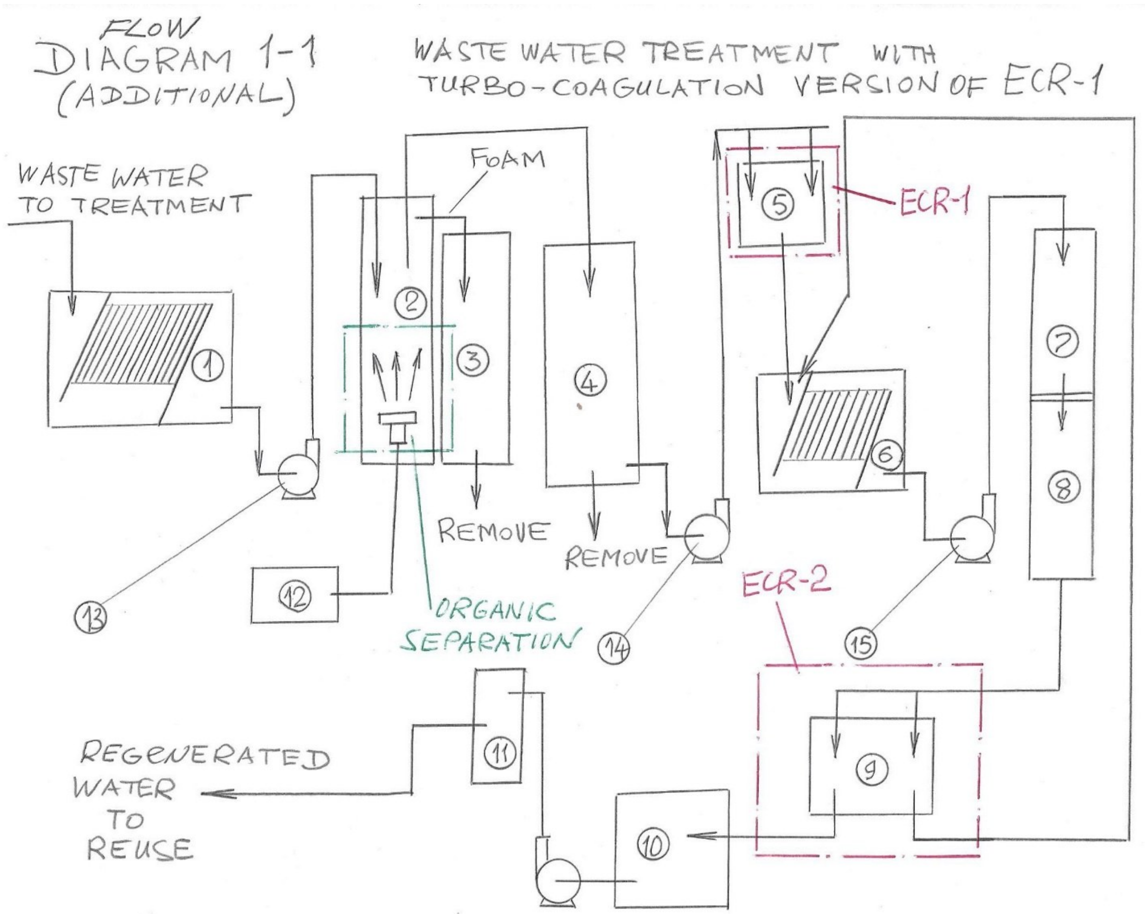
After treatment in the integrated electrochemical reactor, the water is sent to coagulation–sedimentation columns and from there into the clean-water collector, which includes a final aeration subsystem to saturate the water with oxygen up to its maximum level (company technologies under licence from the author of this publication).

Both systems are assembled on a single frame and share a common real-time control and monitoring system (the principles of using combined power sources to reduce energy consumption are company technologies under licence from the author of this publication).

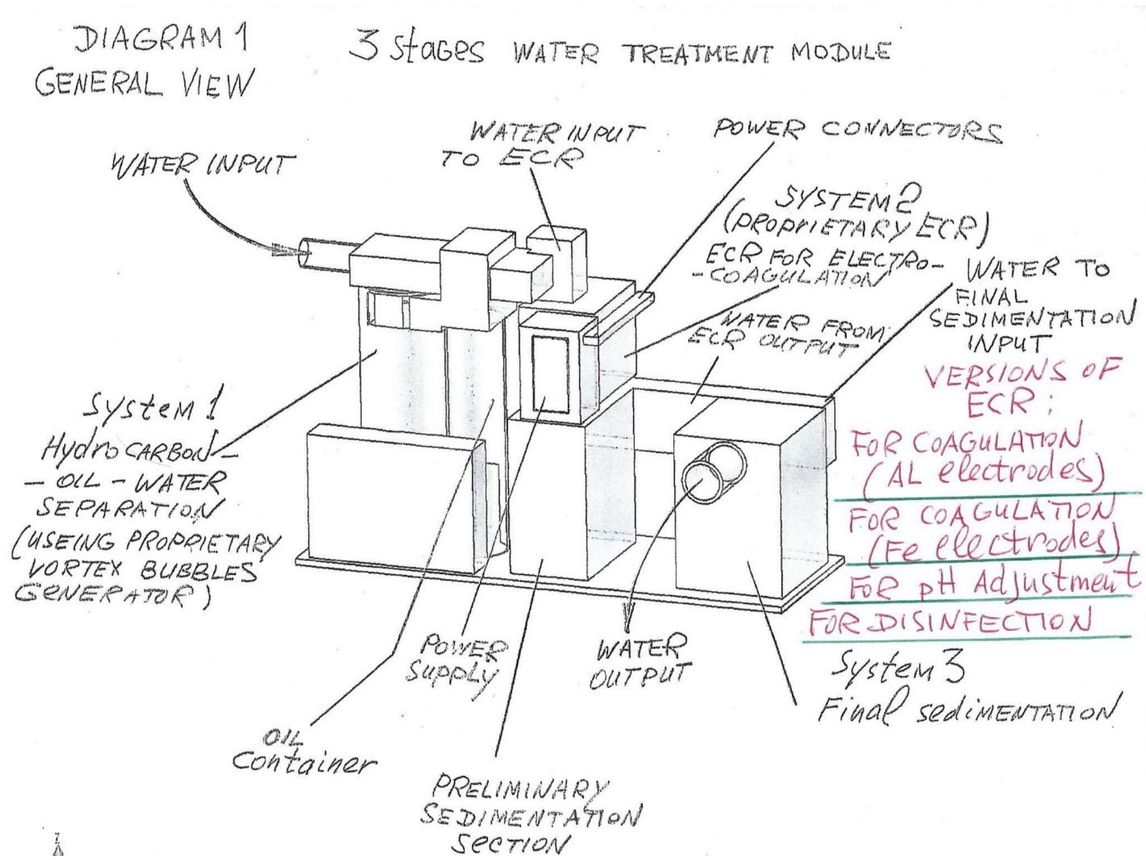
Where necessary, processors with elements of artificial intelligence and artificial neural networks can be connected to and adapted with the systems.

In desert regions, the systems above can be combined with a local autonomous installation for desalinating groundwater by means of accelerated electrolytic treatment in a directed stream of saline groundwater or seawater (company technologies under licence from the author of this publication).

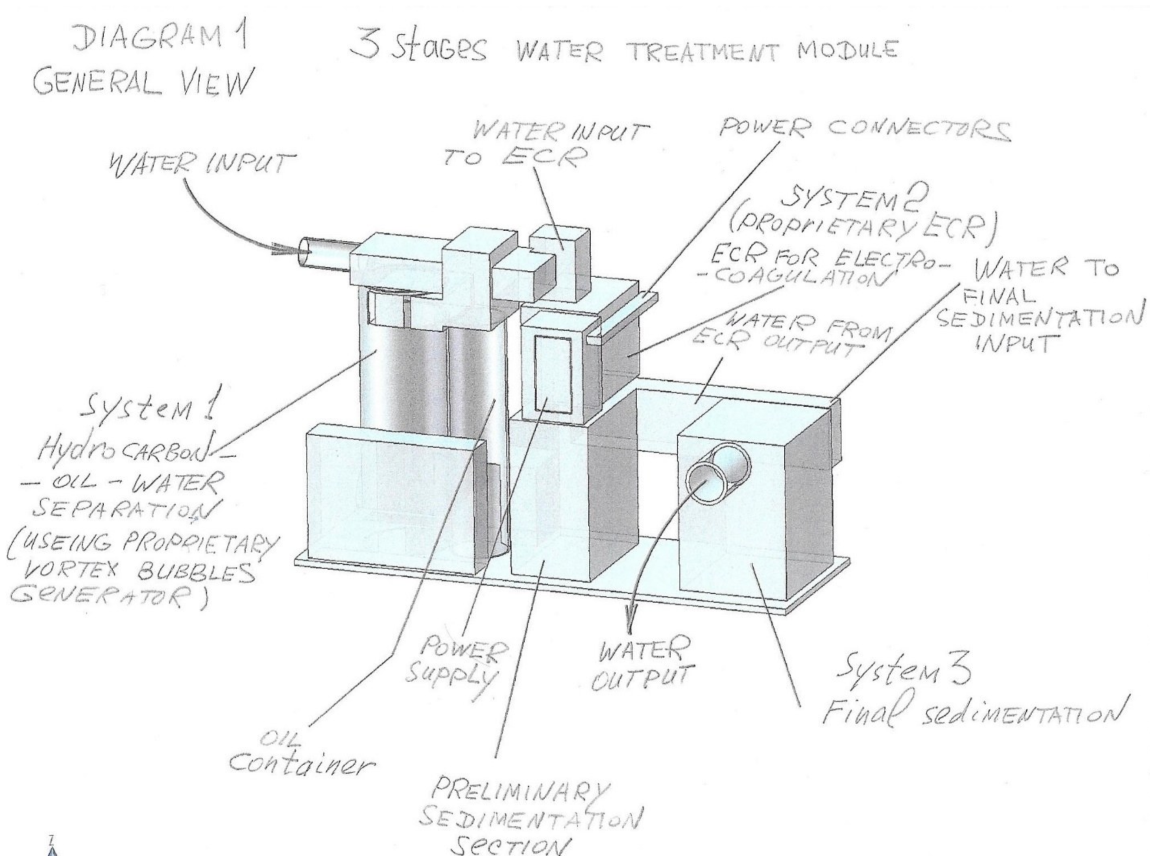
# Appendix 1



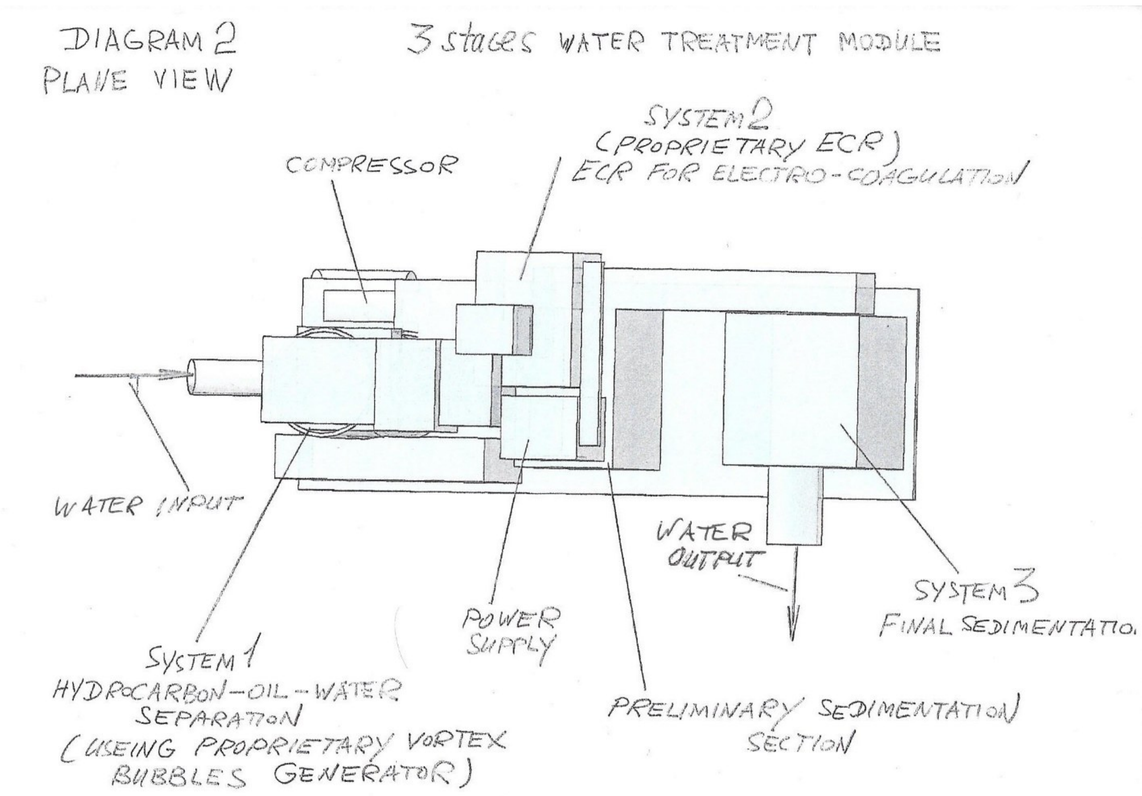

*Appendix 1, Figure 1.*



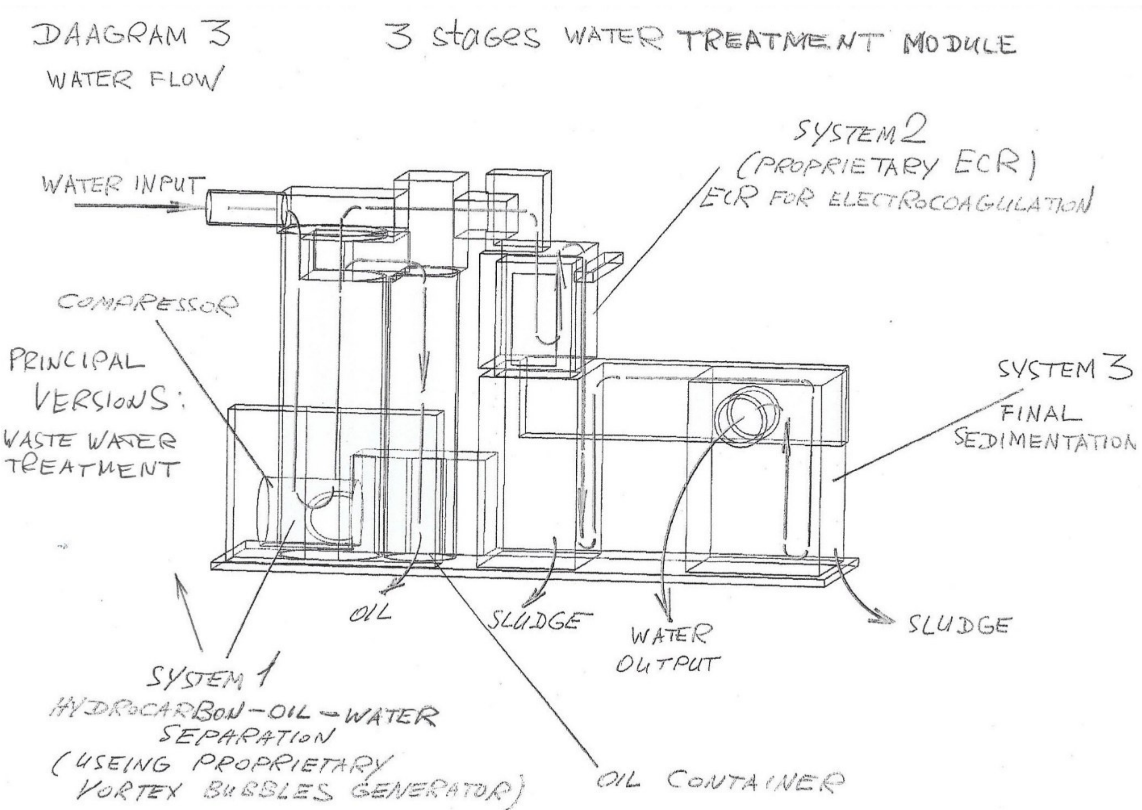

*Appendix 1, Figure 2.*



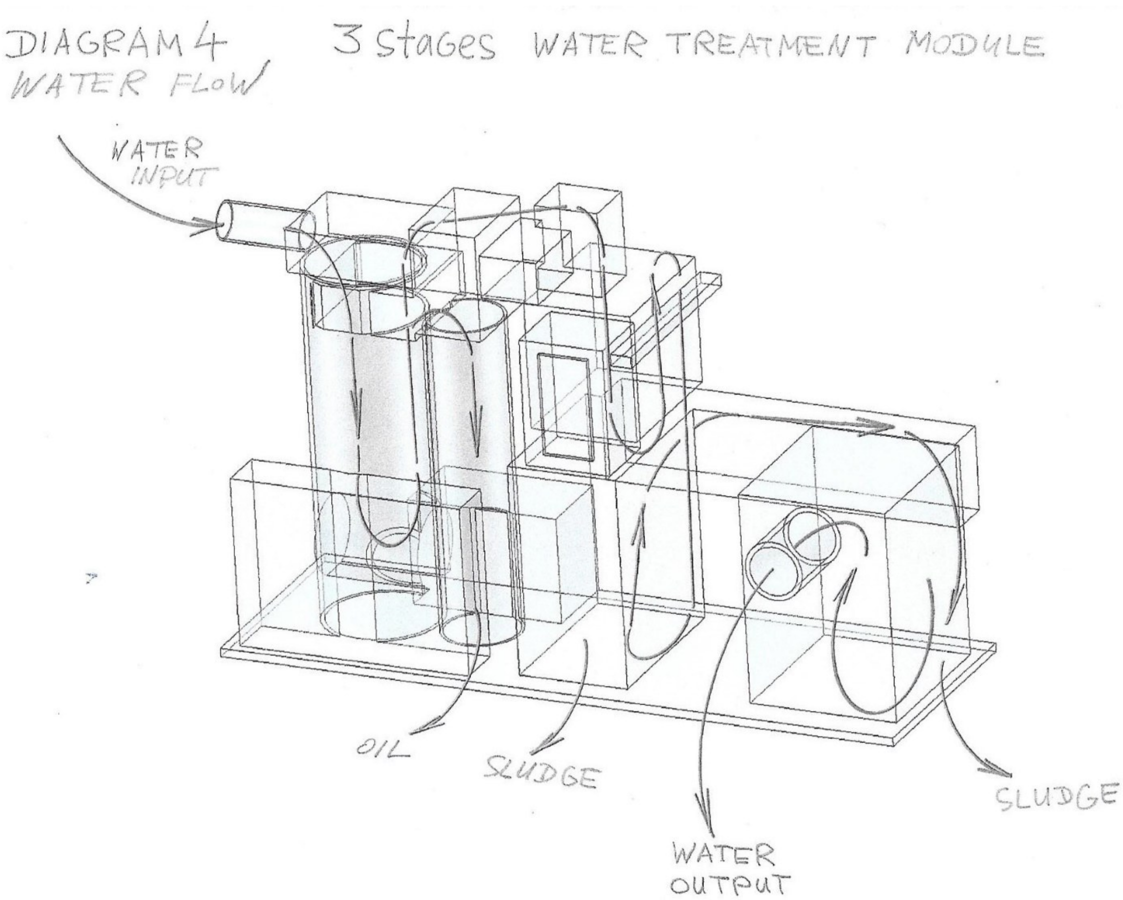

*Appendix 1, Figure 3.*



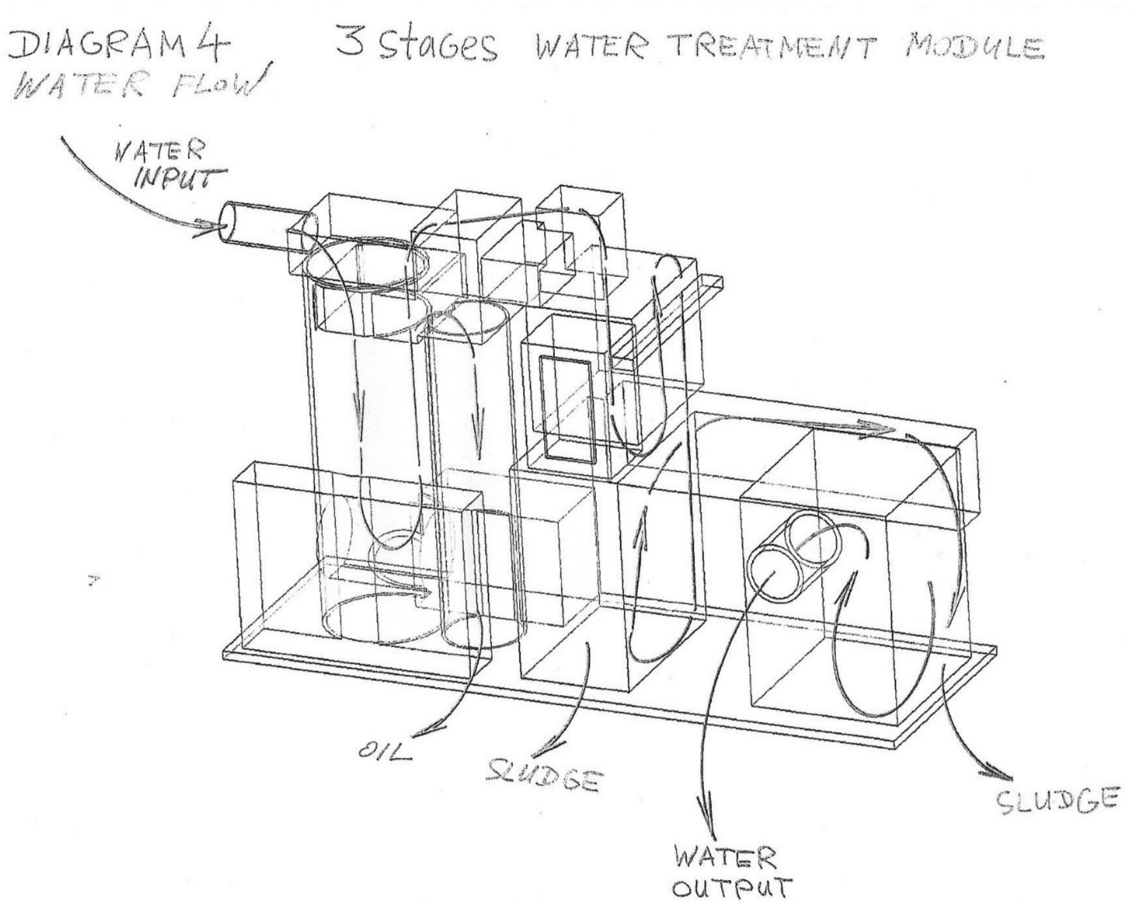

*Appendix 1, Figure 4.*




*Appendix 1, Figure 5.*

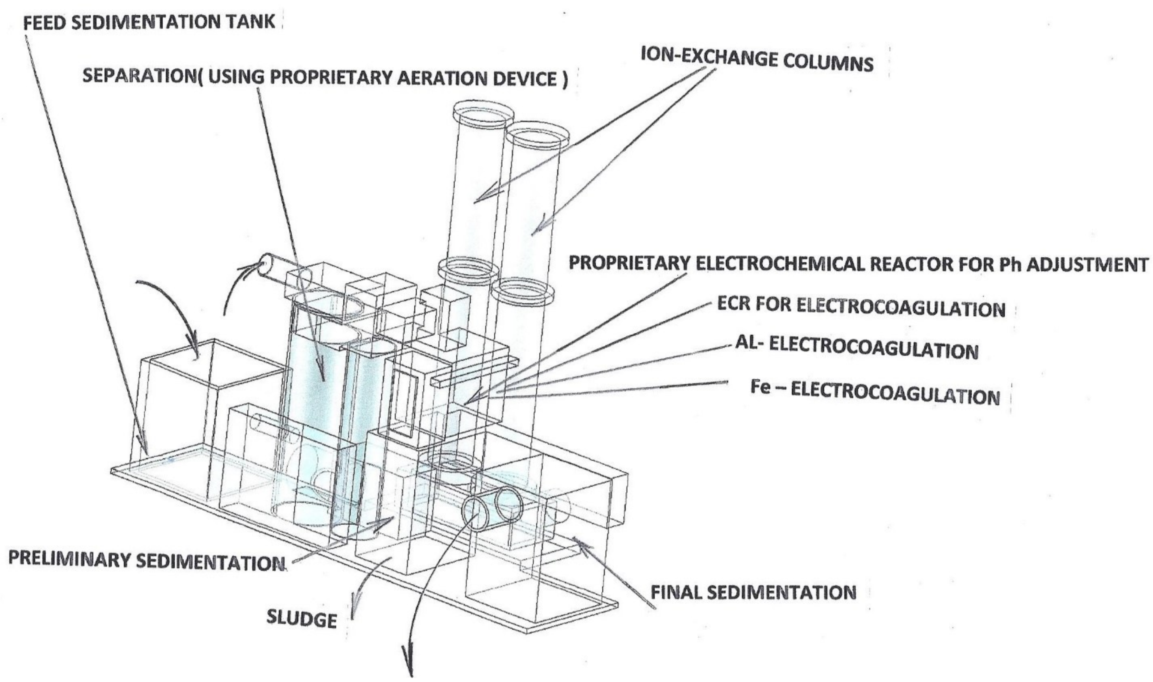



*Appendix 1, Figure 6.*

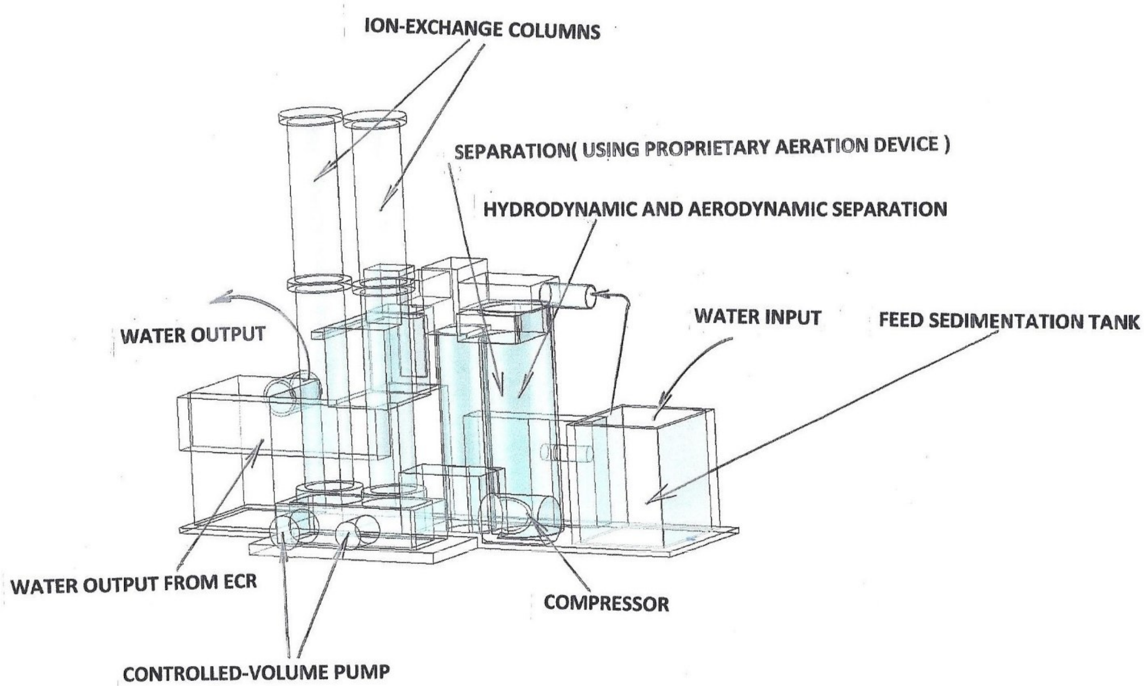



*Appendix 1, Figure 7.*

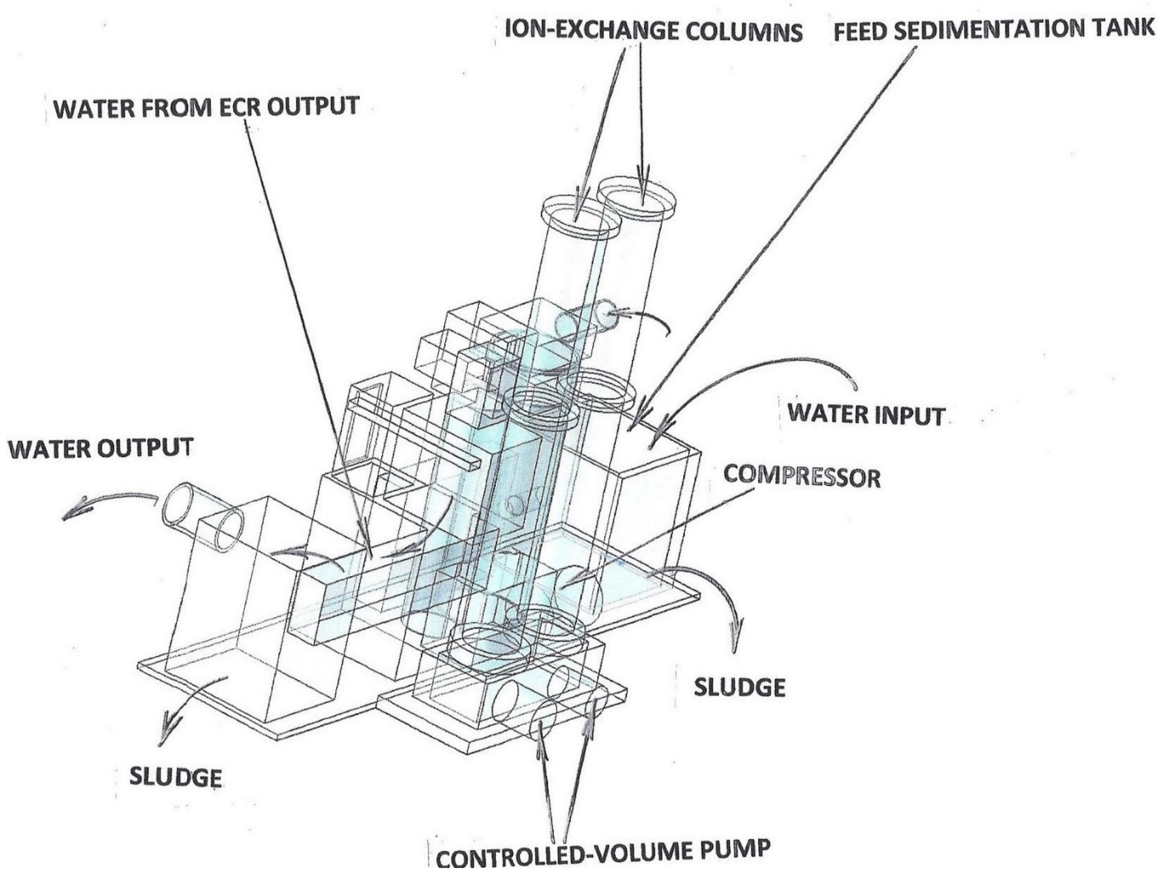
# Appendix 2



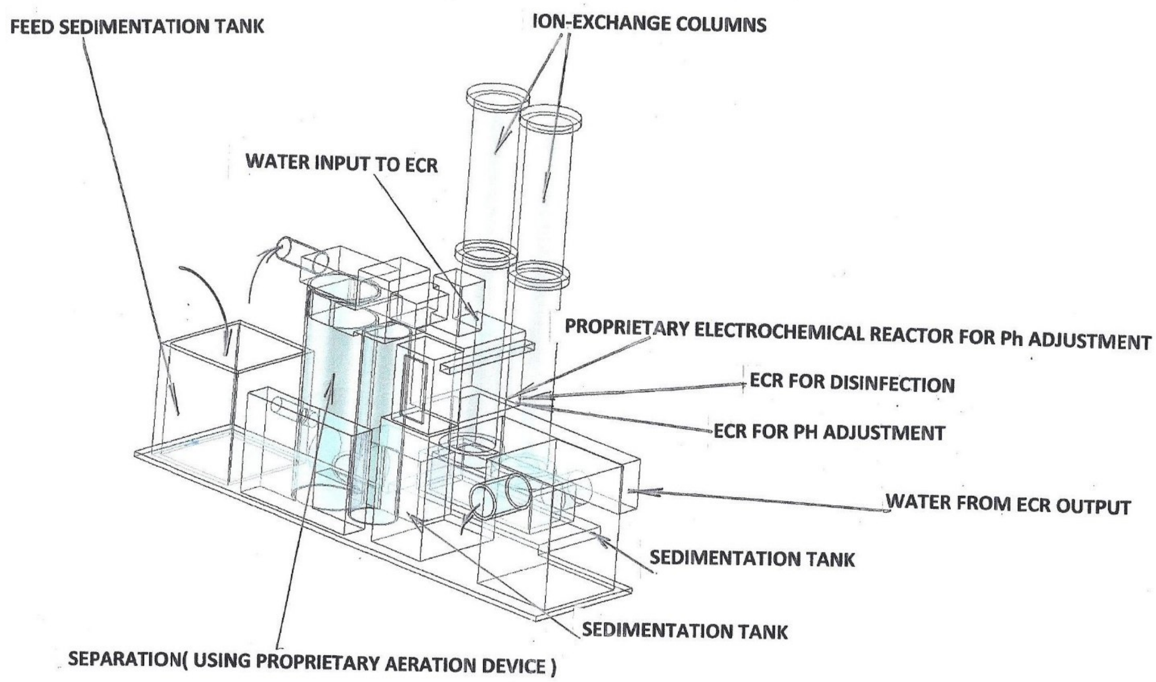

*Appendix 2, Figure 1.*



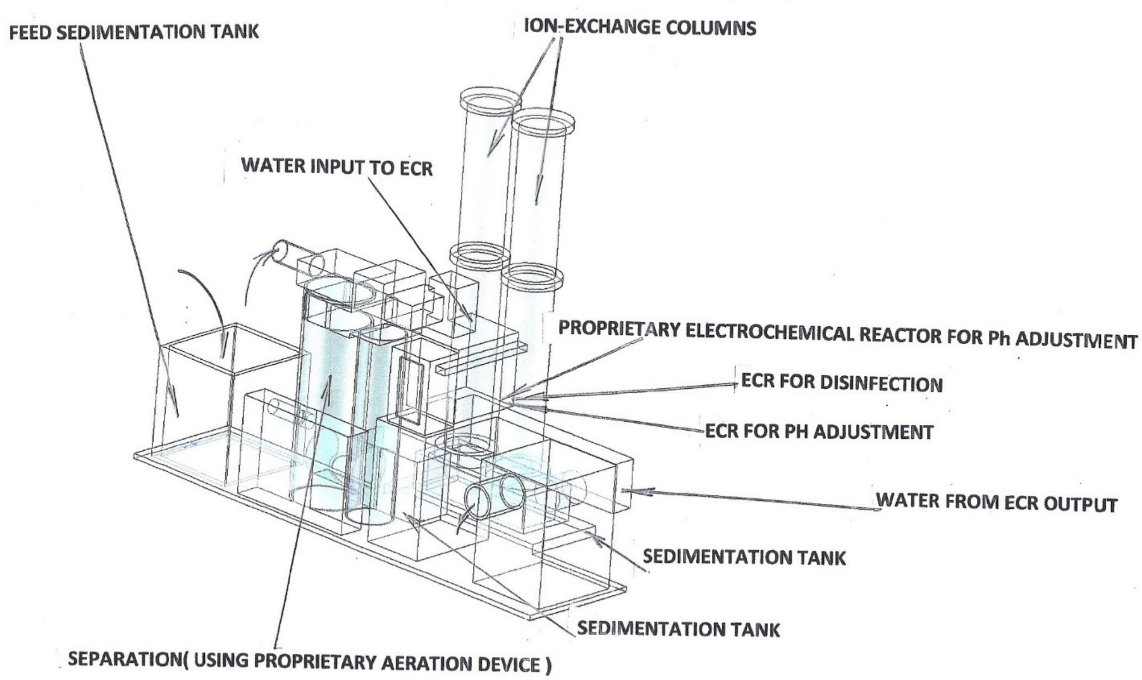
*Appendix 2, Figure 2.*



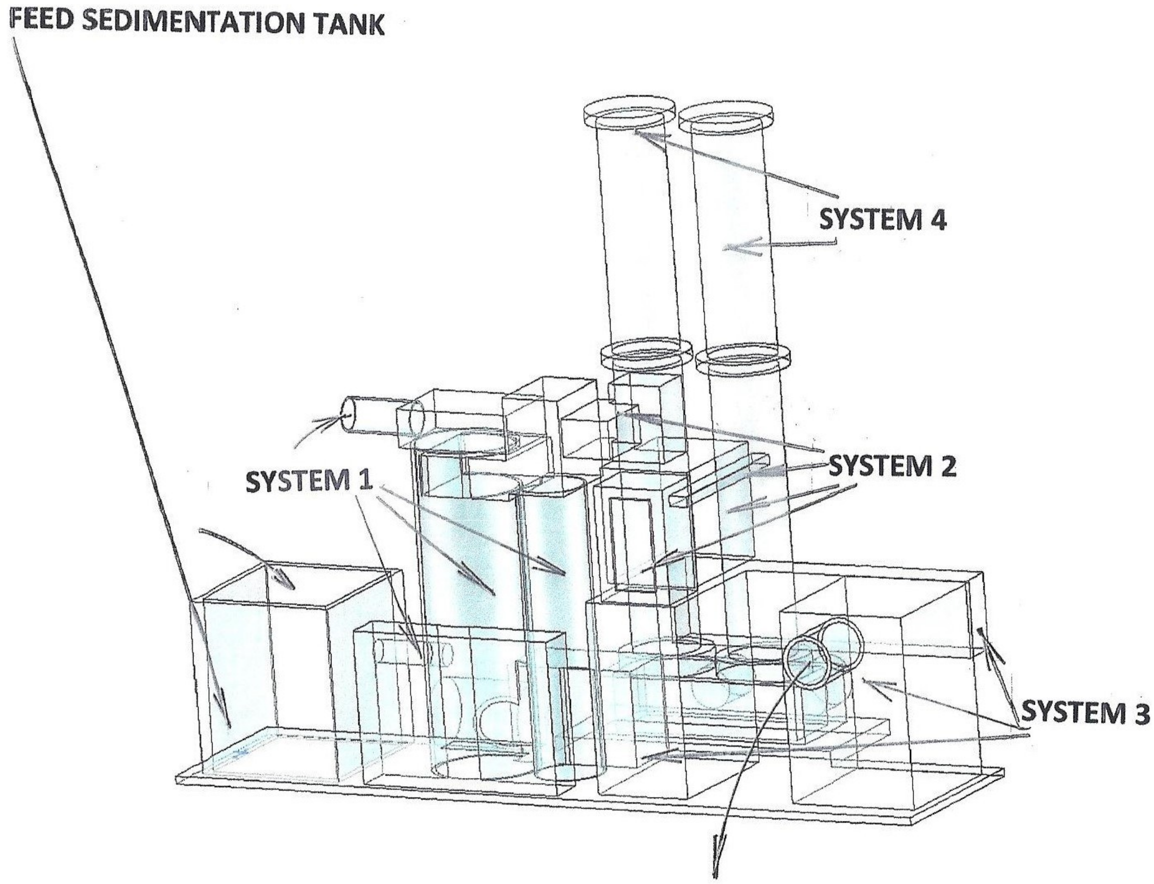

*Appendix 2, Figure 3.*



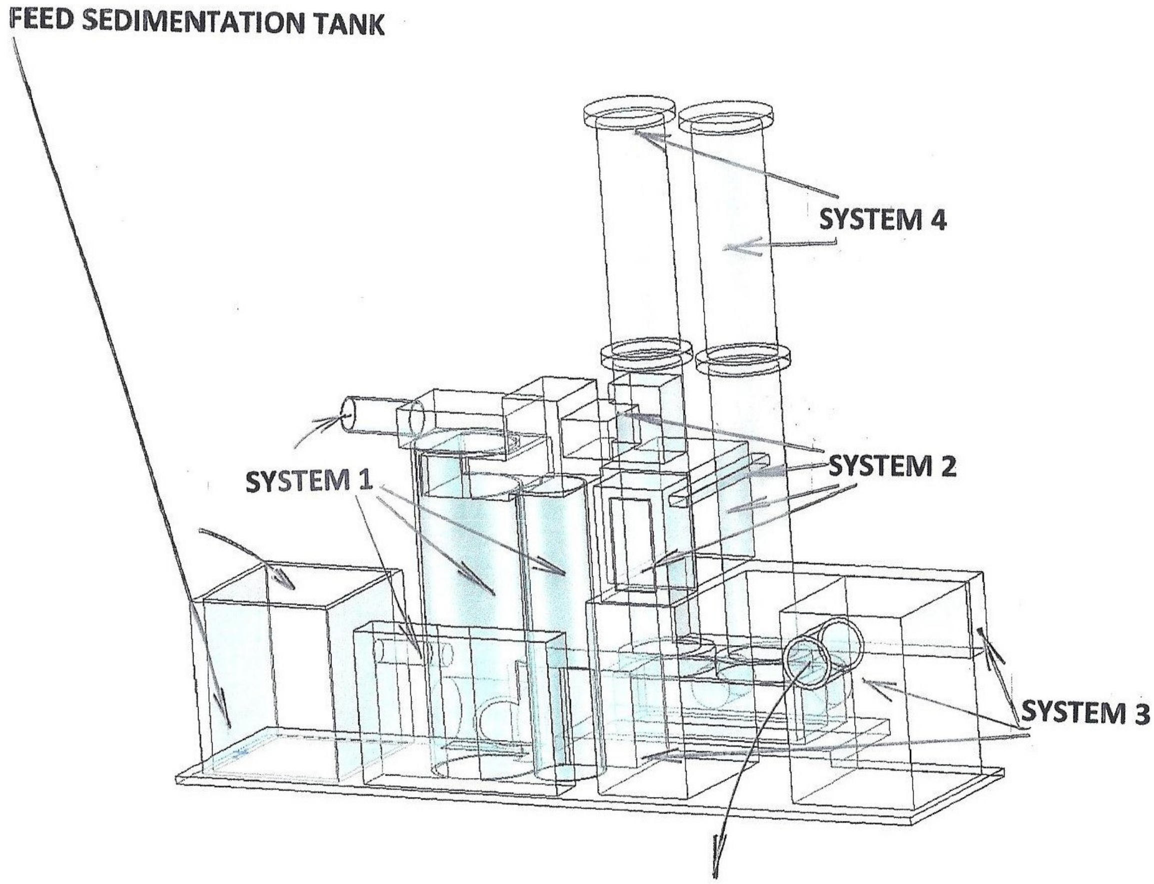

*Appendix 2, Figure 4.*



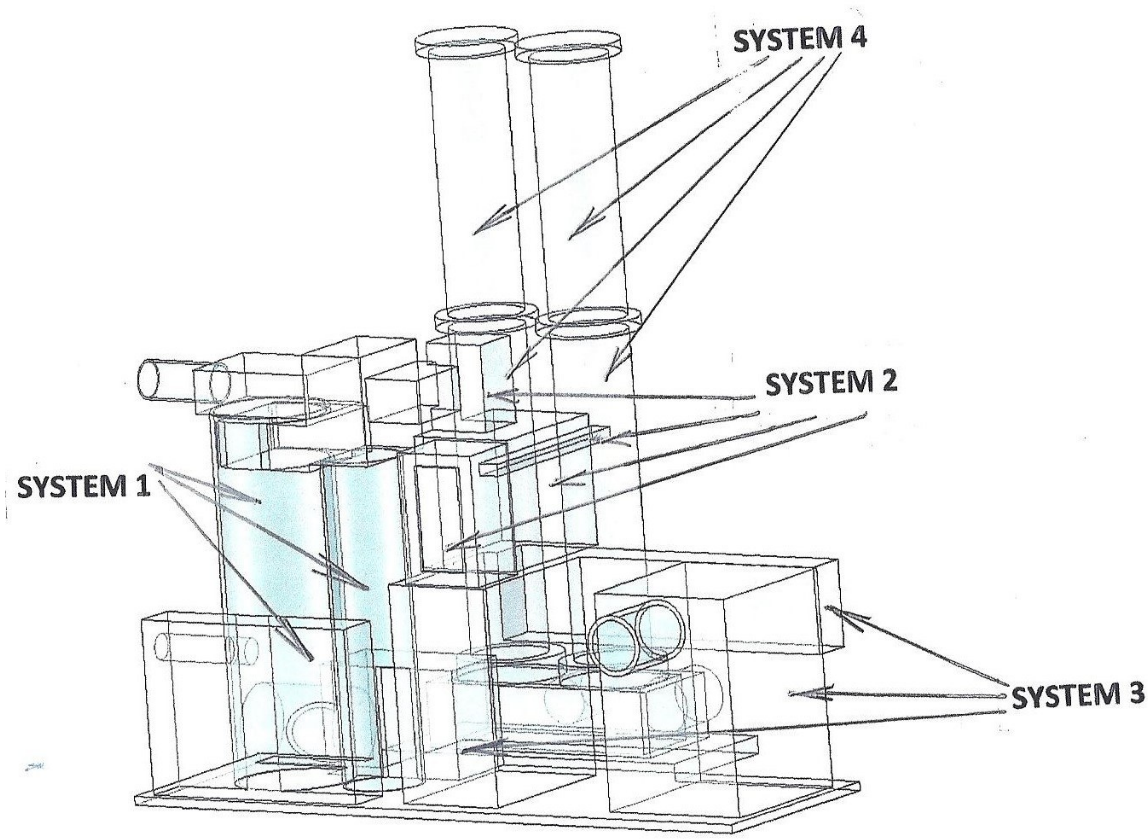

*Appendix 2, Figure 5.*



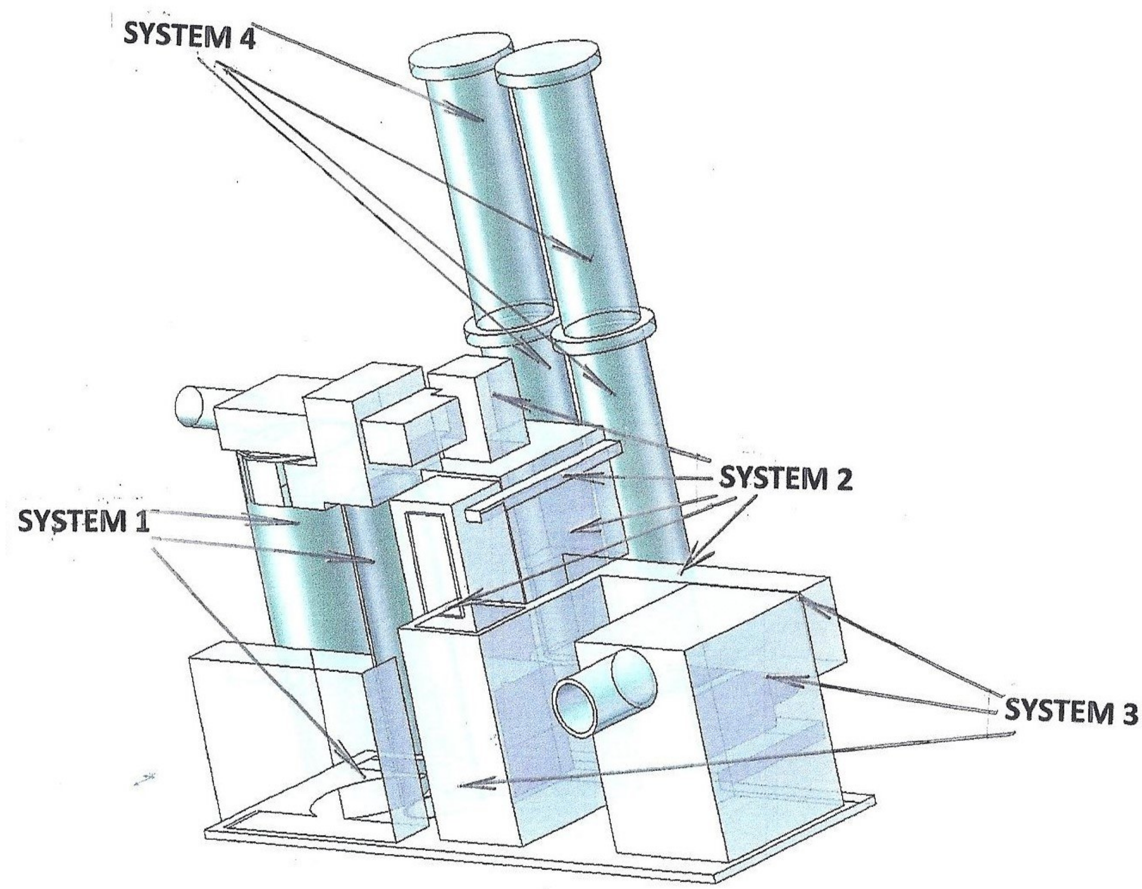

*Appendix 2, Figure 6.*



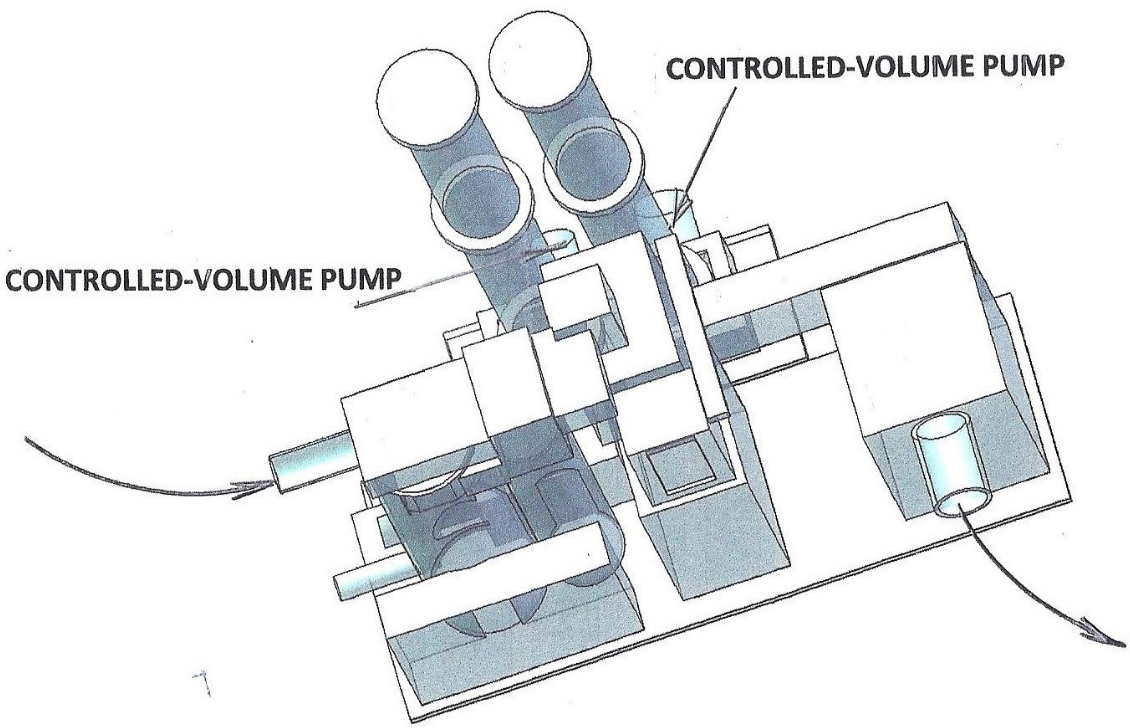

*Appendix 2, Figure 7.*



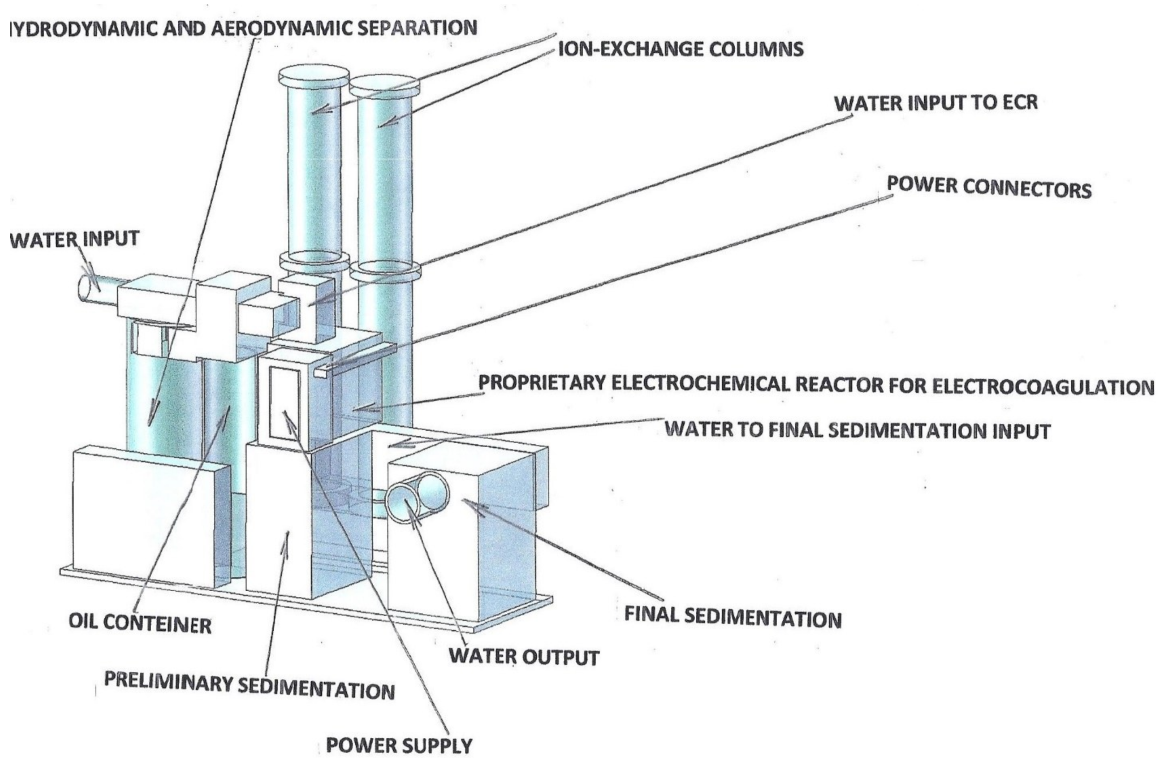

*Appendix 2, Figure 8.*




*Appendix 2, Figure 9.*




*Appendix 2, Figure 10.*




*Appendix 2, Figure 11.*

# Appendix 3

## List of references, patent and licensing information

**APPENDIX 3–1**

| | |
|---|---|
| **United States Patent Application** | **20210094846** |
| **Kind Code** | **A1** |
| **CONNOR, JR.; Michael James; et al.** | **April 1, 2021** |

**HYBRID ELECTROCHEMICAL AND MEMBRANE-BASED PROCESSES FOR TREATING WATER WITH HIGH SILICA CONCENTRATIONS**


**Abstract**

Provided are hybrid electrochemical and membrane-based systems for removing silica from water stream to achieve ultra-pure water. The silica concentration of a feed water stream may dictate the most effective and economical variation of disclosed hybrid processes to use. For example, for a feed water stream having a silica concentration of 1-30 ppm, a hybrid system for treating the feed water includes an electrodialysis reversal unit, the electrodialysis reversal unit comprising an inlet stream and a product outlet stream; a reverse osmosis unit, the reverse osmosis unit comprising an inlet stream and a product outlet stream, wherein the inlet stream of the reverse osmosis unit comprises the product outlet stream of the electrodialysis reversal unit; and an electro-deionization unit, the electro-deionization unit comprising an inlet stream and a product outlet stream, wherein the inlet stream of the electro-deionization unit comprises the product outlet stream of the reverse osmosis unit.


**APPENDIX 3–2**

| | |
|---|---|
| **United States Patent Application** | **20210078887** |
| **Kind Code** | **A1** |
| **YANG; Qifeng; et al.** | **March 18, 2021** |

**TREATMENT PROCESS AND TREATMENT SYSTEM OF ENHANCED UP-FLOW MULTIPHASE WASTEWATER OXIDATION**

**Abstract**

The present disclosure discloses a treatment process and treatment system of enhanced up-flow multiphase wastewater oxidation. The treatment process includes the following steps: 1) the wastewater is fed into the up-flow multiphase wastewater oxidation system for oxidation treatment; 2) the wastewater is fed to the solid-liquid separation system for solid-liquid separation, the separated heterogeneous catalytic carrier (5) is fed back to the up-flow multiphase wastewater oxidation system, and the wastewater is fed to the neutralization and degassing system; 3) the wastewater is fed to the neutralization and degassing system to adjust a pH of the wastewater to 5.5-7.5, and then is degassed by stirring; 4) the wastewater is fed to the flocculation and sedimentation system for sludge-water separation, a supernatant is discharged, and an outward harmless treatment is performed after a pressure filtration of a sedimentary iron sludge.

**APPENDIX 3–3**

| | |
|---|---|
| **United States Patent Application** | **20210060522** |
| **Kind Code** | **A1** |
| **EL-SHALL; M. Samy; et al.** | **March 4, 2021** |

**GRAPHENE-BASED MATERIALS FOR THE EFFICIENT REMOVAL OF POLLUTANTS FROM WATER**

**Abstract**

Materials and methods for removing contaminants from liquids such as water are provided. The materials are graphene oxide-based materials that are chemically modified to comprise functional groups that adsorb a wide variety of pollutants such as heavy metals, nitrates, and phosphates.

**APPENDIX 3–4**

| | |
|---|---|
| **United States Patent Application** | **20210029977** |
| **Kind Code** | **A1** |
| **Alcantar; Norma Arcelia; et al.** | **February 4, 2021** |

**COMPOSITIONS AND METHODS TO REMOVE AMMONIA IN FRESHWATER AND SALTWATER FISH STORAGE SYSTEMS**

**Abstract**

Compositions, systems and methods of removing ammonia from fish storage systems are presented. A chemical water conditioner comprised of sodium formaldehyde bisulfite, cornstarch, dye and alcohol was found to have a high ammonia removal efficiency in seawater. A combination of this chemical water conditioner with modified chabazite and phosphate buffer exhibited high ammonia removal efficiency in both seawater and freshwater.

**APPENDIX 3–5**

| | |
|---|---|
| **United States Patent Application** | **20210002151** |
| **Kind Code** | **A1** |
| **HAO; Xiaogang; et al.** | **January 7, 2021** |

**METHOD AND DEVICE FOR REMOVING CHLORIDE ION IN DESULFURIZED WASTEWATER BY ELECTROCHEMICAL COUPLING**

**Abstract**

The present invention discloses a method and device for removing chloride ions in desulfurized wastewater by electrochemical coupling. In the device, an electrolyte tank is used as a separator in a separation process and as an electrode regenerator in an electrode regeneration process; two electrodes are a hydrogen evolution electrocatalysis function electrode and an electrochemically switched ion exchange (ESIX) function electrode respectively, and the electrodes are connected with each other by a wire; two DC circuits have opposite electric field directions and are alternately used in the separation process and the electrode regeneration process respectively; the bottom of the electrolyte tank is provided with a purified high-concentration chloride ion wastewater inlet and a flocculation product outlet, and the top is provided with a dechlorination treatment water outlet and a hydrogen collecting port; and in the electrode regeneration process, the electrolyte tank is connected to an electrode regeneration liquid storage tank through a pump and a pipeline. In the present invention, by utilizing the synergistic reinforcement of reactions of an anode and a cathode, the chloride ion removal efficiency and energy utilization efficiency can be improved, and finally the chloride ions in wastewater are present in flocculation products in a solid form, which facilitates recycling.

**APPENDIX 3–6**

| | |
|---|---|
| **United States Patent Application** | **20210046431** |
| **Kind Code** | **A1** |
| **AWADH; Tawfik Abdo Saleh; et al.** | **February 18, 2021** |

**SIMULTANEOUS SORPTION OF DYES AND TOXIC METALS FROM WATERS USING TITANIA-INCORPORATED POLYAMIDE**

**Abstract**

A method for making a titania-polymer nanocomposite by simultaneously forming TiO2 nanoparticles in situ from a TiO2 precursor in the presence of urea and interfacially polymerizing polyamide precursors thereby producing a titania-polymer nanocomposite. A titania-polymer nanocomposite made by this method. A method for removing a dye or metal from water comprising contacting contaminated water with the titania-polymer nanocomposite.

**APPENDIX 3–7**

| | |
|---|---|
| **United States Patent Application** | **20200406194** |
| **Kind Code** | **A1** |
| **DEMETER; Ethan** | **December 31, 2020** |

**ELECTRODIALYSIS PROCESS AND BIPOLAR MEMBRANE ELECTRODIALYSIS DEVICES FOR SILICA REMOVAL**

**Abstract**

Provided are electrodialysis systems for removing silica from a desalinated water stream and methods for removing silica from a desalinated water stream. For example, described are bipolar membrane electrodialysis devices for removing silica from water comprising one or more anion exchange membranes; one or more bipolar membranes; and a pair of electrodes comprising a positive electrode and a negative electrode. Also described are electrodialysis systems comprising: one or more electrodialysis devices for the removal of dissolved ions and one or more bipolar membrane electrodialysis devices, wherein a product inlet stream of the one or more bipolar membrane electrodialysis devices comprises the product outlet stream of the one or more electrodialysis devices.

**APPENDIX 3–8**

| | |
|---|---|
| **United States Patent Application** | **20200399148** |
| **Kind Code** | **A1** |
| **AVRAHAM; Eran; et al.** | **December 24, 2020** |

**METHOD AND APPARATUS FOR ELECTROCHEMICAL pH CONTROL**

**Abstract**

The present invention relates to the production of electrolyzed aqueous solutions in an electrochemical cell. More particularly, the invention relates to an asymmetric electrochemical cell device for producing electrolyzed water or aqueous solution, while controlling the pH of the solution. The invention further relates to methods of operating said device and to the use thereof for microbial disinfection and/or pesticide removal.

**APPENDIX 3–9**

| United States Patent Application | 20200381758 |
|---|---|
| Kind Code | A1 |
| SHIUE; Lih-Ren; et al. | December 3, 2020 |

**SYSTEM FOR GENERATING ELECTRICITY USING OXYGEN FROM WATER**

**Abstract**

Oxygen from water can be efficiently and economically achieved via water electrolysis on antimony, nickel doped tin oxide (Sb,Ni-SnO2/Ti) anode using low DC power. As O2 is evolved, it will be quickly reduced by adjacent cobalt oxide doped carbon nanofilm (Co3O4-CNF/Ti) to hydrogen peroxide (H2O2) and electricity. In the said electricity generation, O2 is first formed in O2 evolution reaction (OER), then, electricity is generated in O2 reduction reaction (ORR). Both of anode and cathode are shared by OER and ORR, yet, the former consumes energy and the latter yields electricity. It is the cathode, a load and the anode that form an electricity-forming circuit. The said circuit relies on clean water to supply the fuel, O2, hence, it is designated as all-water fuel cell (AWFC). Supercapacitor is employed as the load for AWFC, and onboard purifiers are providers of clean water for AWFC.

**APPENDIX 3–10**

| United States Patent Application | 20200353129 |
|---|---|
| Kind Code | A1 |
| JAKUS; Adam E.; et al. | November 12, 2020 |

**Water-Soluble Salt Particle Containing Compositions and Porous Materials Made Therefrom**

**Abstract**

Compositions for forming porous materials and three-dimensional objects, including fibers, films and coatings made from the materials are provided. Also provided are methods for forming the porous objects from the compositions. The compositions include a solvent, a polymer binder that is soluble in the solvent, and solid particles that are insoluble in the solvent. The solid particles include water-soluble salt particles that can be selectively dissolved from objects made from the compositions to render the resulting structures porous.

**APPENDIX 3–11**

| United States Patent Application | 20200345585 |
|---|---|
| Kind Code | A1 |
| Dresdner, JR.; Karl P.; et al. | November 5, 2020 |

**Process for making aqueous therapeutic particle having stable exterior water clustering with nanosized thickness**

**Abstract**

The invention relates to processes for making pharmaceutical aqueous therapeutic particles (AQTP) having stable exterior water clustering with nanosized thickness less than 300 nanometers, wherein the AQTP has an improved bioavailability when administered to a mammal compared to conventional pharmaceutical drug particles administered to the mammal. The invention relates to an improved process apparatus which is computer controlled, capable of continuous operation with high efficiency so as to make a more consistently acceptable AQTP compared to a previous prototype process apparatus of the Inventors. The invention provides compositions comprising of AQTP which comprise a substance selected from the group consisting of a cannabinoid such as CBD, a cell membrane pore-forming peptide such as PNC-27, a psychoactive drug, a pharmaceutical, a nutraceutical, a mineral, an anion, a cation, a protein, a peptide, an amino acid, a polymer, a vitamin, an antioxidant, a fertilizer, a chemical, a medical use product, a medical kit use product, a personal consumer use product, a manufacturing use product, an energy use product such as a battery, and any combination thereof.

**APPENDIX 3–12**

| United States Patent Application | 20200283920 |
|---|---|
| Kind Code | A1 |

| | |
|---|---|
| **Bairamijamal; Faramarz** | **September 10, 2020** |

**PROCESS FOR ENRICHMENT OF THE CO2 CONCENTRATION IN THE CO2-STREAMS FROM THE POST-COMBUSTION AND PRE-COMBUSTION STATIONARY SOURCES OF CO2 EMISSION UPSTREAM OF FURTHER PROCESSING**


**Abstract**

The present process invention in continuation to the U.S. Ser. No. 14/392,066 appertains to Advanced Combustion in post-combustion carbon capture, wherein the CO2-containing flue gas, said CO2-Stream, is cleaned from harmful constituents, recirculated, oxygenized and employed for combustion for the fossil fuels, referred to Flue Gas Oxy-Fueling in order to obtain a CO2-rich gas upstream to CO2-CC with significantly less gas flow rate subject to further processing. This continuation process patent also presents processing to prepare a CO2-rich CO2-Stream for the pre-combustion carbon capture downstream of gasification and gas cleaning process; or from the secondary CO2-Stream that stems from the cathodic syngas [CO/2H2] downstream of HPLTE-SG of patent parent, then downstream of the HP/IP-water shift converters in [CO2/3H2] composition, whereas the CO2-rich CO2-Stream from either pre-combustion process is routed to the CO2-CC for CO2 cooling and condensation section of the U.S. Ser. No. 14/392,066 to obtain liquid carbon dioxide for re-use as new fossil energy resource.


**APPENDIX 3–13**

| | |
|---|---|
| **United States Patent Application** | **20200262728** |
| **Kind Code** | **A1** |
| **Mykytiuk; Oleksandr Yuriiovych** | **August 20, 2020** |

**THE METHOD FOR TREATMENT AND DISINFECTION OF INDUSTRIAL EFFLUENTS**


**Abstract**

The invention relates to the methods for sewage treatment contaminated by mechanical impurities, fats, proteins and other organic and inorganic compounds, and can be used for purification and water disinfection contaminated by heavy and radioactive metals, saturated or unsaturated fats, filtrate from landfills for solid household waste, disposals of meat processing plants, and water contaminated with oil and petroleum products. The method for treatment and disinfection of industrial wastewater includes flotation, electrocoagulation and filtration. The new is that the method also provides: mixing water with powder hydrophobic carbon-based sorbent with high absorbing capacity; filtration of a suspension of water and a carbon sorbent on a rubber-based hydrophobic sorbent; decomposition of saturated and

unsaturated fat, oil, petroleum products and other organic substances accumulated on carbon and rubber sorbents; floatation in flow mode with the addition of hydrogen peroxide; recovery of the active substance in the presence of hydrogen peroxide; and its further reuse; electrocoagulation in flow mode with water saturation with oxygen and hydrogen, formed on indispensable carbon or metal electrodes, and on the active substance based on the of aluminum, titanium, sodium, tin, copper, and other metals; water disinfection by electro-cavitation; generation of active substance based on the iron and titanium atoms; water filtration on the precoat filter, filtering on activated carbon filter.

**APPENDIX 3–14**

| | |
|---|---|
| **United States Patent Application** | **20200147553** |
| **Kind Code** | **A1** |
| **James; Patrick Ismail** | **May 14, 2020** |

**METHOD FOR ELECTROCHEMICAL SEPARATION AND REGENERATION OF FORWARD OSMOSIS DRAW SOLUTION**


**Abstract**

A device for controlling acidity of electrolytes and the oxidation states or concentrations of selected constituents for treatment of liquid media using electricity for electrochemical separation and regeneration of forward osmosis draw solutions includes a FO unit arranged for osmotic solvent separation from a feed water stream, and an electrochemical solvent separation and draw solution regeneration unit incorporating an electrochemical cell, arranged to use diluted draw solutions to generate a concentrated draw solution, a TPW stream and an osmotic agent. The concentrated draw solution may be arranged to reenter the forward osmosis unit.


**APPENDIX 3–15**

| | |
|---|---|
| **United States Patent Application** | **20200123029** |
| **Kind Code** | **A1** |
| **Kornbluth; Mordechai C.; et al.** | **April 23, 2020** |

**CONVERSION MATERIALS FOR ELECTROCHEMICAL REMOVAL OF CHLORIDE-CONTAINING SALTS FROM WATER**

**Abstract**

A device for removing chloride-containing salts from water includes a container configured to contain saline water, a first electrode arranged in fluid communication with the saline water, and a power source. The first electrode includes a conversion material that is substantially insoluble in the saline water and has a composition that includes at least two or more of aluminum, chlorine, copper, iron, oxygen, and potassium. The composition varies over a range with respect to a quantity of chloride ions per formula unit. The power source supplies current to the first electrode in a first operating state so as to induce a reversible conversion reaction in which the conversion material bonds to the chloride ions in the saline water to generate a treated water solution. The conversion material dissociates the chloride ions therefrom into the saline water solution in a second operating state to generate a wastewater solution.

**APPENDIX 3–16**

| United States Patent Application | 20200123027 |
|---|---|
| Kind Code | A1 |
| Kornbluth; Mordechai C.; et al. | April 23, 2020 |

**CONVERSION MATERIALS FOR ELECTROCHEMICAL WATER SOFTENING**

**Abstract**

A water softening device includes a container configured to contain water, first and second electrodes arranged in fluid communication with the water, and a power source. The first electrode includes a conversion material that has a first composition and a second composition coexisting with the first composition. The first composition includes calcium ions bonded thereto and the second composition includes sodium ions bonded thereto. The power source supplies current in a first operating state such that the second composition exchanges sodium ions for calcium ions in the water to generate a soft water solution. The first and second electrodes are connected in a second operating state such that the first composition exchanges calcium ions for sodium ions in the water to generate a wastewater solution. The conversion material undergoes a reversible conversion reaction to convert between the first and second compositions within the water stability window.

**APPENDIX 3–17**

| United States Patent Application | 20200087233 |
|---|---|
| Kind Code | A1 |

| | |
|---|---|
| **ONO; Akihiko; et al.** | **March 19, 2020** |

**CARBON DIOXIDE ELECTROLYTIC DEVICE AND METHOD OF ELECTROLYZING CARBON DIOXIDE**

**Abstract**

A carbon dioxide electrolytic device includes: an electrolysis cell including a cathode, an anode, cathode and anode flow paths, and a separator; a carbon dioxide source to supply carbon dioxide to the cathode flow path; a solution source to supply an electrolytic solution containing water to the anode flow path; at least one sensor to acquire at least one data of a data indicating a discharge amount per unit time of a liquid containing water to be discharged from at least one flow path and a data indicating a concentration of at least one ion in the liquid; a refresh material source including a gas source to supply a gaseous substance to the at least one flow path; and a controller programmed to stop the supply of the carbon dioxide and the electrolytic solution, and start supply of a gaseous substance from the refresh material source, in accordance with the at least one data.

**APPENDIX 3–18**

| | |
|---|---|
| **United States Patent Application** | **20200087174** |
| **Kind Code** | **A1** |
| **Rajic; Ljiljana** | **March 19, 2020** |

**SYSTEMS AND METHODS FOR ELECTROCHEMICALLY ENHANCED WATER FILTRATION**

**Abstract**

A system for electrochemically enhanced water filtration is provided. The system includes: a chamber plug-flow electrochemical cell; a first cathode and anode pair disposed in the cell; and a second cathode and anode pair disposed in the cell. The first and the second pair are collectively operative to apply a 2D electric field in at least one of a horizontal direction and a vertical direction with respect to the chamber plug-flow electrochemical cell.

**APPENDIX 3–19**

| | |
|---|---|
| **United States Patent Application** | **20200048114** |
| **Kind Code** | **A1** |
| **IBANEZ BOTELLA; Juan Miguel; et al.** | **February 13, 2020** |

## SYSTEM FOR WATER DISINFECTION USING ELECTROPORATION

### Abstract

A system for water disinfection by means of electroporation, comprising a reactor (1) composed of a plurality of electrodes that form an electrolytic cell, where they act as a plurality of anodes (2) and cathodes (3); a circuit that allows the water to be confined within the electrolytic cell and to flow through it between the water inlet point into the cell (4) and the water outlet point (5); a pump (6) used to propel the water through the reactor; at least one direct current source (7), which is connected to the reactor (1); and at least one device for process control (PLC) (8). The system produces the irreversible electroporation of bacterial membrane by applying specific electric potentials that alter the transmembrane potential and cause the oxidation of the exposed chemical groups in membrane proteins.

## APPENDIX 3–20

| United States Patent Application | 20200024173 |
|---|---|
| Kind Code | A1 |
| Scheu; Dirk | January 23, 2020 |

## PROCESS AND APPARATUS FOR ENRICHING SILICATE IN DRINKING WATER

### Abstract

Disclosed is a process for enriching silicate content in drinking water that includes separating raw water via reverse osmosis into a permeate comprising demineralised raw water and a retentate comprising mineral enriched raw water. The permeate is mixed with a water glass solution comprising sodium silicate and/or potassium silicate. An ion exchange process is used to reduce the concentration of sodium and/or potassium ions in at least part of the mixture. At least part of the retentate is supplied to the mixture after reducing the concentration of sodium and/or potassium ions to provide a silicate-enriched drinking water. Also disclosed is an apparatus for producing a drinking water enriched with silicate. The apparatus includes a reverse osmosis unit, a mixing unit, an ion exchanger, and a feed unit for feeding at least part of the retentate to the mixture after reducing the concentration of sodium and/or potassium ions.

APPENDIX 3–21

| United States Patent Application | 20200024157 |
|---|---|
| Kind Code | A1 |
| Kano; Ichiro; et al. | January 23, 2020 |

A METHOD FOR PRODUCING ULTRAPURE WATER


Abstract

The present invention relates to a method for producing purified water comprising a step (a) of passing water through a mixed bed ion exchanger comprising beads having a diameter between 0.2 and 0.7 mm and a step (b) of passing water through a fibrous ion-exchange material. The invention further relates to a module comprising the mixed bed ion exchange resin and the fibrous material and to a water treatment system for producing ultrapure water comprising the mixed bed ion exchange resin and the fibrous material.


APPENDIX 3–22

| United States Patent Application | 20190380313 |
|---|---|
| Kind Code | A1 |
| LAHAV; Ori; et al. | December 19, 2019 |

PHYSICO-CHEMICAL PROCESS FOR REMOVAL OF NITROGEN SPECIES FROM RECIRCULATED AQUACULTURE SYSTEMS


Abstract

The present invention provides processes for removing nitrogen species from fresh water or high salinity water recirculated aquaculture systems. The processes are based on physico-chemical treatments which are performed at ambient temperatures and at low pH values thus keeping the total ammonia nitrogen concentrations below a value which is considered detrimental for the growth or survival rate of cultured fish/shrimp.


APPENDIX 3–23

| United States Patent Application | 20190359506 |
|---|---|

| | |
|---|---|
| **Kind Code** | **A1** |
| **HAWKS; Steven; et al.** | **November 28, 2019** |

**SYSTEM AND METHOD FOR HIGH EFFICIENCY ELECTROCHEMICAL DESALINATION**


**Abstract**

The present disclosure relates to a capacitive deionization (CDI) system for desalinating salt water. The system may have a capacitor formed by spaced apart first and second electrodes, which enable a fluid flow containing salt water to pass either between them or through them. An input electrical power source is configured to generate an electrical forcing signal between the two electrodes. The electrical forcing signal represents a periodic signal including at least one of voltage or current, and which can be represented as a Fourier series. One component of the Fourier series is a constant, and a second component of the Fourier series is a sinusoidal wave of non-zero frequency which has the highest amplitude of the additive components of the Fourier series. The amplitude of the sinusoidal wave component is between 0.85 and 1.25 times the amplitude of the periodic signal.


**APPENDIX 3–24**

| | |
|---|---|
| **United States Patent Application** | **20190308893** |
| **Kind Code** | **A1** |
| **CHOI; Hyun Sung; et al.** | **October 10, 2019** |

**BIPOLAR CDI ELECTRODE, BIPOLAR CDI ELECTRODE MODULE AND WATER TREATMENT APPARATUS USING THE SAME**


**Abstract**

A bipolar capacitive deionization (CDI) electrode includes a circular current collector having a central hole and inner and outer circumferential surfaces; a nano-carbon coating layer formed on at least top and bottom surfaces of the circular current collector; and a hydrophobic polymer coating layer respectively disposed over the inner and outer circumferential surfaces of the current collector. Maintenance and management is facilitated by a bipolar CDI electrode module configured such that individual parts are formed to be removably attached. A water treatment apparatus including the bipolar CDI electrode module exhibits high water treatment efficiency, superior long-term stability, and easy maintenance and management, while solving terminal corrosion problems due to the formation of a hydrophobic polymer coating layer on the surface of an electrode terminal.

**APPENDIX 3–25**

| United States Patent Application | 20190302087 |
|---|---|
| Kind Code | A1 |
| Kahn; Malcolm; et al. | October 3, 2019 |

**APPARATUS FOR MEASURING WATER HARDNESS USING ION SELECTIVE ELECTRODE**

**Abstract**

An apparatus for determining total hardness in a fluid stream utilizing an ion exchange column in a monovalent cationic form having an inlet and an outlet, where one or more monovalent ion selective electrodes are positioned either at an inlet, outlet, or at both locations simultaneously. The monovalent cation selective electrodes are in electrical communication with one another, and in fluid communication with one or more valves incorporated within a fluid path in order to introduce feed water/softened water to the monovalent cation selective electrodes. Additionally, one blending valve may be incorporated in the ion exchange column to allow a fraction of the feed (hard) water to mix with a fraction of the softened water. In this manner, the blending valve may be utilized to adjust the hardness of the water at the output.

**APPENDIX 3–26**

| United States Patent Application | 20190300393 |
|---|---|
| Kind Code | A1 |
| FLECKNER; Karen; et al. | October 3, 2019 |

**FLUID TREATMENT SYSTEMS AND METHODS OF USING THE SAME**

**Abstract**

A fluid treatment system that includes a sonic energy generator and an electromagnetic field generator is described herein. The fluid treatment system may include a controller that independently controls the sonic energy generator and the EMF generator while in use. Also described herein are methods of treating a fluid including applying a sonic signal to at least a portion of the fluid, and applying an electromagnetic field signal to at least the portion of the fluid by a direct conductive path. Methods of

treating water that has been extracted by an atmospheric water generator unit using such a fluid treatment system are also described herein.

**APPENDIX 3–27**

| United States Patent Application | 20190256376 |
|---|---|
| Kind Code | A1 |
| LESHUK; Timothy Michael Carter; et al. | August 22, 2019 |

**COMPOSITE MATERIAL FOR WATER TREATMENT**


**Abstract**

A composite material for use in water treatment. The composite material includes a porous matrix including a resin capable of retaining a catalyst and magnetic material therein, and includes a density regulating portion disposed therein. The catalyst is capable of facilitating a chemical reaction involving contaminants in the water. The magnetic material and density regulating portion can be used to separate the composite material from treated water. Systems and methods of use involving passive water treatment, continuous water treatment, solar light exposure, UV light exposure, and electrochemical cells, employing photochemical, electrochemical, and photoelectrochemical reactions are described. Methods of manufacture are described.