European Journal of Technical and Natural Sciences 2026, No 4
ISSN 2414-2352

PREMIER Publishing
ppublishing.org

DOI:10.29013/EJTNS-26-4-68-72

INTEGRATED WATER REGENERATION MODULES FOR SMART HOME INFRASTRUCTURE (Integrated comprehensive water regeneration module with preparation for recirculation; the entire water regeneration process is carried out without the use of chemical reagents, forming the basis of an integrated, comprehensive, multifunctional process for the regeneration of wastewater at a single facility within a smart home infrastructure or its equivalents)

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Cite: *Khabarova A. (2026). Integrated Water Regeneration Modules For Smart Home Infrastructure. (Integrated comprehensive water regeneration module with preparation for recirculation; the entire water regeneration process is carried out without the use of chemical reagents, forming the basis of an integrated, comprehensive, multifunctional process for the regeneration of wastewater at a single facility within a smart home infrastructure or its equivalents). European Journal of Technical and Natural Sciences 2026, No 4.* https://doi.org/10.29013/EJTNS-26-4-68-72

Abstract

The invention relates to integrated technologies for water treatment, purification, regeneration, and preparation for recirculation within the infrastructure of smart homes and smart mobile homes. The proposed technology is based on a set of autonomous modular units that can be combined in various configurations depending on the operating conditions and the required water treatment objectives.

The integrated system comprises an inlet water treatment module, ion-exchange treatment modules, electrochemical reactor modules with metallic and composite electrode cells operating in single-flow and dual upward-flow configurations, mechanical filtration modules, and final sedimentation modules. The inlet and final treatment modules incorporate foam generation systems, sedimentation systems for foam-separated contaminants, oxygen saturation systems, microbubble and nanobubble aeration systems, and non-contact water quality monitoring devices based on electromagnetic resonance spectroscopy.

The ion-exchange module utilizes sectional columns containing encapsulated synthetic, natural, and biological ion-exchange materials and is equipped with pumps, flow sensors, pressure gauges, check valves, and control valves. The electrochemical treatment modules include electrochemical reactors, power supply units, processor-based control systems, and non-contact real-time acidity monitoring sensors, providing efficient treatment of water and aqueous solutions, including radioactive water.

The proposed modular architecture enables flexible integration of individual treatment technologies into a unified multifunctional water regeneration complex. Each module possesses independent technical novelty while simultaneously providing synergistic performance when operating as part of the integrated system. The invention ensures comprehensive purification, regeneration, and preparation of used water for reuse without the application of chemical reagents, improving treatment efficiency, process reliability, environmental safety, and adaptability to modern smart infrastructure

Keywords: *Module; Water regeneration module; Fundamental modules and core operations of an integrated water purification and regeneration technology for smart home water treatment infrastructure; Chemical-free water regeneration process; Integrated multifunctional water regeneration process; Processor-based control and monitoring system with non-contact real-time pH sensors; Dual upward-flow electrochemical reactor module with metallic electrode cells*

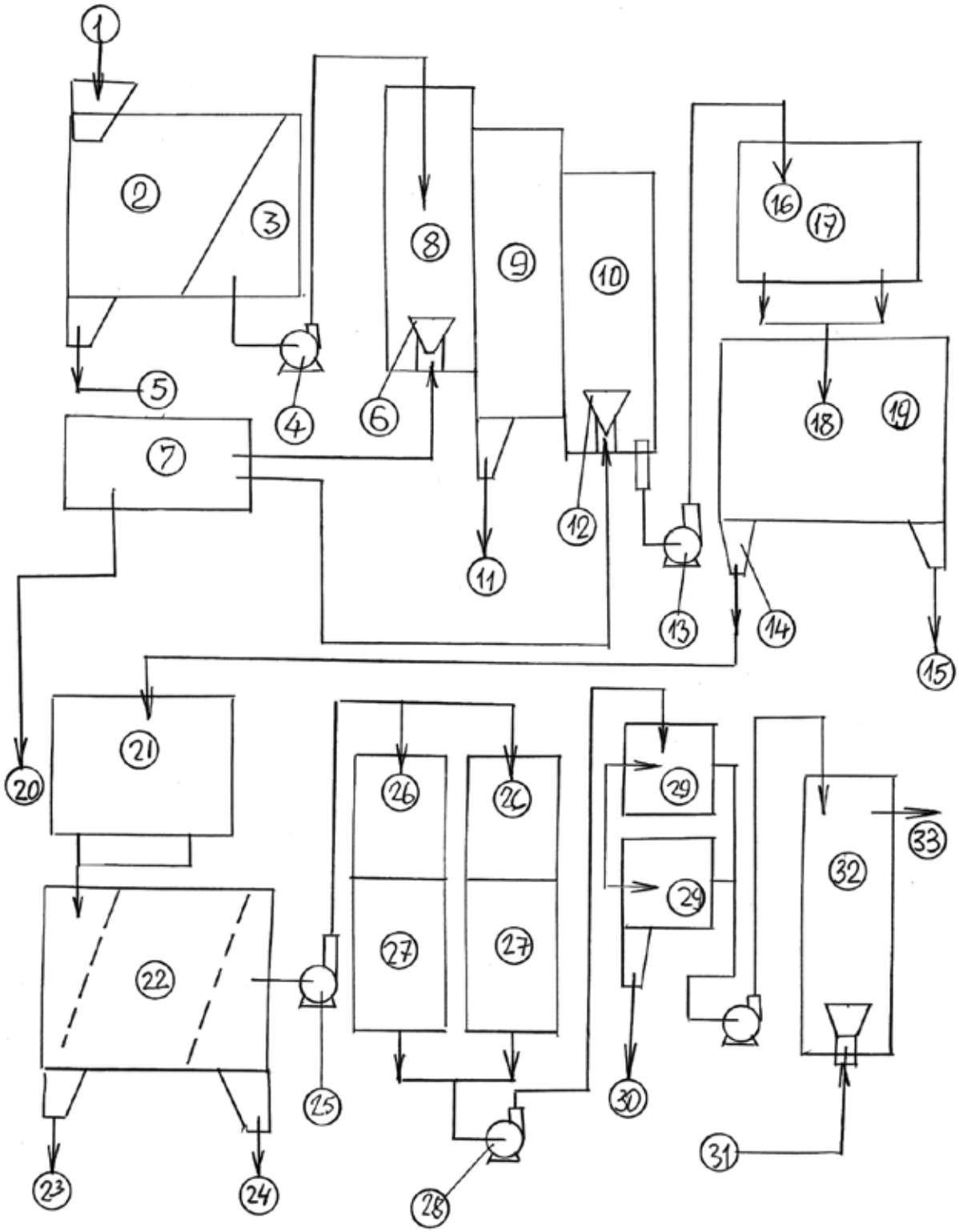
Introduction:

Integrated comprehensive module for water purification and regeneration within a smart home infrastructure system.

The ion-exchange module utilizes sectional columns containing encapsulated synthetic, natural, and biological ion-exchange materials and is equipped with pumps, flow sensors, pressure gauges, check valves, and control valves. The electrochemical treatment modules include electrochemical reactors, power supply units, processor-based control systems, and non-contact real-time acidity monitoring sensors, providing efficient treatment of water and aqueous solutions, including radioactive water. The proposed modular architecture enables flexible integration of individual treatment technologies into a unified multifunctional water regeneration complex. Each module possesses independent technical novelty while simultaneously providing synergistic performance when operating as part of the integrated system. The invention ensures comprehensive purification, regeneration, and preparation of used water for reuse without the application of chemical reagents, improving treatment efficiency, process reliability, environmental safety, and adaptability to modern smart infrastructure.

Figure 1.

Figure 2.



Integrated comprehensive water regeneration module with preparation for recirculation

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

The integrated comprehensive multifunctional process for the regeneration of water used at a single facility comprises the following systems:

- Inlet sedimentation without additional treatment;

- Foam treatment with separation of sediment fractions and organic contaminants;
- Separation of the foamed contaminant complex from contaminant-free liquid;
- Secondary aeration of the separated water with dissolution of oxygen to the level of complete saturation;
- Comprehensive treatment of water in an electrochemical reactor operating according to a multifunctional process, including pH adjustment, disinfection, dosing of coagulants or flocculants, and restoration of the water streams to a common pH level;
- Sedimentation within the discharge flow of water containing coagulants or flocculants;
- Repeated multifunctional treatment of the water stream from the sedimentation tank containing coagulants or flocculants according to the following final process: pH adjustment, disinfection, and restoration of the entire treated water stream to the specified common pH level;
- Final sedimentation of all water treated in the second electrochemical reactor;
- Treatment in ion-exchange columns, including sections filled with natural granular zeolite instead of synthetic ion-exchange resin;
- Treatment in automated self-cleaning mechanical filters or membrane filters;
- Final aeration using an aerodynamic vortex foam generator with dissolution of oxygen to the level of complete saturation.

The diagram illustrates:

1. Inlet sedimentation tank for the accumulated sediment, including sediment removal functions and transfer of sediment-free water to the subsequent treatment stage;

2. Sedimentation section of tank 1;

3. Sediment-free water collection section of tank 1;

4. Pump for transferring sediment-free water to subsequent treatment stages;

5. System for removal of water containing accumulated sediment;

6. Aerodynamic vortex foam generator;

7. Compressor supplying three aerodynamic vortex foam generators;

8. Column for vortex foaming of sediment-free water;

9. Column receiving foam discharged from the upper section of column 8, intended for aerodynamic vortex foaming of sediment-free water;

10. Column for vortex foaming, aeration, and dissolution of oxygen in the treated water to the level of complete saturation;

11. Contaminant discharge from column 9 receiving foam from the upper section of column 8;

12. Intermediate aerodynamic vortex foam generator;

13. Pump supplying water, after treatment in column 10 with maximum air content and oxygen dissolved to complete saturation, to the electrochemical cells of the first electrochemical reactor in the direction of water flow.

The proposed technology integrates multiple water treatment processes into a single comprehensive regeneration system, ensuring efficient removal of suspended solids, organic contaminants, microorganisms, and dissolved impurities. The sequential combination of sedimentation, electrochemical treatment, ion-exchange purification, filtration, and final aeration provides a high level of treatment efficiency while maintaining stable water quality throughout the process. A significant advantage of the system is its reagent-free operation, which minimizes the use of chemicals, reduces secondary waste generation, and lowers environmental impact. The incorporation of natural granular zeolite as an ion-exchange material further enhances the sustainability and economic efficiency of the technology by reducing dependence on synthetic resins. Owing to its modular design and integrated multifunctional approach, the system can be adapted for a wide range of industrial and municipal water treatment applications requiring reliable, environmentally friendly, and cost-effective water regeneration.

References, Patent and Licensing Information

Kendrick, D., et al. **Ultra Low Emissions Firetube Boiler Burner.** United States Patent Application No. US 20190368723 A1, December 5, 2019.

Choi, Y.-H. **Boiler with Heating Blower.** United States Patent Application No. US 20190249899 A1, August 15, 2019.

Giannoni, R., et al. **Heat Exchange Cell for a Heating Boiler.** United States Patent Application No. US 20190277536 A1, September 12, 2019.

Bograd, A., et al. **Gas Turbine and Method of Operating the Same.** United States Patent Application No. US 20190277193 A1, September 12, 2019.

Hong, S.-H. **Boiler Facility and Operating Method Thereof.** United States Patent Application No. US 20190203927 A1, July 4, 2019.

Pisani, G. **Method for Converting a Gas Boiler into a Liquid-Fuel Boiler.** United States Patent Application № US 20190093918 A1, March 28, 2019.

Carlier, T. M. **System and Methods for Detecting, Monitoring, and Removing Deposits on Boiler Heat Exchanger Surfaces Using Vibrational Analysis.** United States Patent Application No. US 20190041201 A1, February 7, 2019.

Pisani, G. **Boiler for Producing Hot Water or Steam.** United States Patent Application No. US 20190093879 A1, March 28, 2019.

Joffroy, J.-M. **Thermodynamic Boiler with Thermal Compressor.** United States Patent Application No. US 20190055932 A1, February 21, 2019.

Mozo, I., et al. (2020). *Method and Device for Treating Wastewater*. United States Patent Application No. US 20200377396 A1. Published December 3, 2020.

Mahajan, D. (2020). *Method and Apparatus for Treating Wastewater Using Non-Chemical Process*. United States Patent Application No. US 20200377382 A1. Published December 3, 2020.

Ginestet, P. (2020). *Reactor and Method for Biological Treatment of Wastewater*. United States Patent Application No. US 20200346958 A1. Published November 5, 2020.

Kowalski, M. S., et al. (2020). *Dynamic Process Control for Partial Nitritation in Wastewater Treatment with Autotrophic Nitrogen Removal*. United States Patent Application No. US 20200346956 A1. Published November 5, 2020.

submitted 16.06.2026;
accepted for publication 30.06.2026;
published 31.07.2026

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