

ELECTROCATALYSIS WATER TREATMENT

Technological Field

The present disclosure relates to methods of water treatment. More specifically, the present disclosure relates to the use of electrocatalysis for the treatment and purification of water.

Background

Methods of water treatment typically depend upon the type of water being treated. The broadest spectrum of treatments is used for treating agricultural and industrial waste water. Treatment methods include biological, chemical, physical, and oxidative methods. Biological treatment methods, such as the use of aerobic and anaerobic bacteria, take a long period of time, and require large areas of land and continual maintenance. Physical treatment uses filtration, absorbance, and sedimentary processes to treat the water. Chemical treatment relies upon the addition of chemicals to precipitate pollutants or initiate their gaseous release. However, physical and chemical treatment methods have low efficiency and may cause secondary pollution.

Drinking water purification typically employs filtration, chlorine, chlorine dioxide, or ozone. Filtration can be costly as membranes suitable for water filtration are expensive. Chlorine gas can produce halides, which are dangerous to the environment and potentially carcinogenic to the human body. Use of chlorine dioxide reduces the risk of halide production but may result in high chloride ion levels in the water. The chloride ions may interact with other ions in the water to form harmful substances. Ozone is costly and if there is bromine present in the water, carcinogenic bromate, such as potassium bromate may form.

Purification of water used in pools, spas, ponds, and fountains is typically performed with chemical disinfectants, UV radiation, or ozone. These methods may require

complex facilities and high maintenance fees. Chemical disinfectants can damage skin and hair as well as aquatic organisms.

New methods of waste water treatment, capable of treating any type of waste water in a manner that removes contamination without the expense or chemical pollution caused by traditional treatment methods, are needed.

Summary

The present disclosure includes a method of water purification including exposing a quantity of water to an electrical current in a container.

The present disclosure further includes an apparatus for water purification including a container; at least one electrode; and, a power supply, wherein the electrode is located within the container and the electrode is operatively connected to the power supply.

The present disclosure also includes a system for water purification including an apparatus comprising at least one electrode operatively connected to a power supply; a pipe operatively connected to the apparatus; a water source operatively connected to the pipe.

The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

Brief Description of Drawings

Embodiments of the disclosure are described herein with reference to the drawings in which:

FIG. 1 is a depiction of an embodiment of an apparatus in accordance with the present disclosure;

FIG. 2 is a depiction of an embodiment of a system of the present disclosure;

FIG. 3 is a depiction of an embodiment of an alternative system of the present disclosure; and,

FIG. 4 is a depiction of another embodiment of a system of the present disclosure.

Detailed Description

In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein.

The present disclosure provides a water treatment method and system that utilizes electrocatalytic oxidation. Electrocatalytic oxidation allows for oxidation of organic compounds, ammonia compounds, and heavy metals. Organic compounds can decompose into carbon dioxide gas and hydrogen gas. Ammonia compounds can oxidize into nitrogen and hydrogen gasses. Heavy metals can be oxidized and form metal hydroxides that precipitate out of the water and can then be physically removed. Atomic oxygen and hydrogen gas generated during the process can enhance the process of oxidation and suspend contaminants in bubbles on the surface of the water forming a foam that can then be physically removed.

In accordance with the present disclosure, an apparatus that includes at least one electrode is provided. Waste water can enter the apparatus containing the electrode and contaminants in the waste water can undergo electrocatalytic oxidation. One or more apparatuses can be used. The waste water can be recycled through a single

apparatus or transferred sequentially through two or more apparatuses. In embodiments where two or more apparatuses are used, waste water can enter the first apparatus at a top corner and exit at a bottom corner then enter the second apparatus at a top corner. The gravitational flow of the waste water over the electrodes and through the system can conserve both time and energy.

In some embodiments, waste water can be brought from an external source, through pipes, into the apparatus to form a system. The external source can be, for example, a truck carrying a waste water tank, pipes or tanks collecting effluent from, for example, street run-off, manufacturing or production processes, agricultural waste water, and the like. In other embodiments, water may be from a source continuously connected to the apparatus forming a system. Sources continuously connected to the apparatus may include, for example, a pool, spa, pond, decorative water fountain, and the like.

In embodiments, valves may be used to control the speed and quantity of waste water moving through the apparatus(es). Control of any valves, power to the electrode(s), and other features such as, for example, an air pump, can be from a control unit. The control unit can be operatively connected to the apparatus(es).

An embodiment of an apparatus for electrocatalytic oxidation of waste water is depicted in FIG. 1. The apparatus 10 includes a container 12. The container 12 can include an intake tube 14, an outlet tube 16, a gas exhaust port 18, a cleaning port 20, and a discharge port 22. Inside the container 12 is a reactor unit 24. The reactor unit 24 can include one or more electrodes 26. The electrodes 26 can be affixed to the reactor unit 24 by non-reactive substance such as a polymer (not shown) to secure the electrodes 26 to the reactor unit 24. The electrodes 26 can include cathodes 30 and anodes 28 operatively connected to a power supply 32. The power supply 32 can be operatively connected to a control unit 34.

The container 12, intake tube 14, outlet tube 16, reactor unit 24 of FIG. 1 and pipes (not shown) can be made, for example, of stainless steel, or other non-reactive metal or a non-reactive polymer.

The reactor unit 24 can include one or more electrodes 26. In some embodiments, the cathodes 30 and anodes 28 of electrodes 26 can have a length of, for example from about 10 mm to about 1000 mm. In some embodiments, the cathodes 30 and anodes 28 of electrode can have a length of about 200 mm to about 500 mm. In some embodiments, the width of each cathodes 30 and anodes 28 of electrode 26, can be, for example from about 20 mm to about 50 mm. In some embodiments, the thickness of cathodes 30 and anodes 28 of each electrode 26 can be, for example, from about 0.5 mm to about 2 mm. In some embodiments, the cathodes 30 and anodes 28 of electrode can have a thickness of about 0.5 mm to about 1.2 mm. In some embodiments, the cathode 28 and anode 30 of the electrode 26 can be separated, for example, by greater than about 0.25 mm to about 5 mm. In some embodiments, the cathode 30 and anode 28 of the electrode 26 can be separated, for example, by about 0.25 mm to about 1.5 mm; in some embodiments, by about 2 mm to about 5 mm.

The small distance between the cathode and anode of each electrode, and between the electrodes of the present disclosure allows for very compact construction with a high rate of purification in a small chamber. In embodiments, the electrodes can be separated by about 100 mm. In some embodiments, the electrodes are separated by more than 100 mm. The maximum distance of electrode separation is where the electrical current no longer conducts through the water. Thus, the maximum distance of electrode separation is dependent upon the strength of the electrical current emitted by each electrode and the conductivity of water.

Any number of electrodes can be used in an apparatus for water purification, for example, between 2 electrodes and 1200 electrodes can be used in an apparatus. In

embodiments, at least two electrodes are used to form an apparatus. In some embodiments, two to 100 electrodes can be used to form an apparatus.

In embodiments where there is more than one electrode 26 in a reactor unit 24, the electrodes can be connected in series with staggered cathodes 30 and anodes 28.

In some embodiments, the cathodes can be titanium. Unlike either platinum or copper, which are commonly used in such devices, titanium is not consumed by the electrocatalytic processes taking place in the apparatus. Thus, these cathodes and anodes of the electrode can be placed much closer together. The anodes can be coated. The coating can be, for example, a metal oxide, for example, an oxide of platinum, rhodium, ruthenium, iridium, tantalum, palladium, tin, titanium, a porcelain modified oxide, a boron doped diamond, and the like and combinations of these.

The material from which each electrode of an apparatus is constructed, and the coating on the cathodes and anodes of electrode, can be independently selected for maximum effectiveness. In embodiments, each electrode of an apparatus includes the same material and coating. In some embodiments, each electrode of an apparatus is made of a different material/coating combination. In some embodiments, a first number of electrodes having a first material/coating combination are combined with a second number of electrodes having a second material/coating combination. The types of material/coating electrode combinations, the number of electrodes included, and the order of layering of these electrodes in an apparatus can vary according to the level of contamination of the water and the degree of purification desired. In embodiments, there can be more than one cathode and more than one anode per electrode, the ratio of cathodes to anodes is 1:1. The electrodes of the apparatus can be connected in parallel or in series.

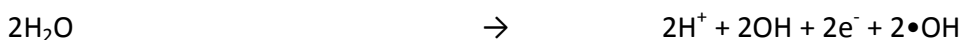
In embodiments, the total surface area of the cathode can be greater than the total surface area of the anode. In embodiments the ratio of the surface area of the anode to the surface area of the cathode can be, for example, from about 1:1 to about 1:1.5. The cathode and anode can be in any form, for example, rod, net, plate, and the like.

The electrodes 26 can be connected to a power supply 32. The power supply 32 can utilize alternating current (AC) or direct current (DC). The voltage of the current can be any voltage. In embodiments, the voltage is about 36 V. In embodiments, the electric density of the electrodes 26 can be, for example, about 0.1 A/dm² to about 10 A/dm². In embodiments, the electric density of the electrodes 26 can be from about 1 A/dm² to about 2 A/dm². In embodiments, the voltage between the electrodes 26 should be from about 8 V to about 36 V.

The control unit 34 can include controls for one or more functions of the apparatus 10. The control unit 34 can include, for example, a control for the voltage or current applied, controls for water intake and outflow, and the like.

Purification/treatment of the water is induced by the electrodes. Hydrogen ions and peroxides are generated on the surface of the cathode, and hydroxyl radicals, and oxygen gas are generated at the anode. These ions initiate redox reactions that oxidize contaminants in the water. Heavy metals are also attracted to the cathode and adhere to the cathode. Thus, the cathode itself removes metallic contaminants from the water. Examples of the reactions that can be induced are depicted below:

At the electrodes:



Organic compounds



Ammonia compounds



Heavy metal compounds



M can be selected from a heavy metal, such as, for example, chromium, lead, nickel, copper, cadmium and the like, and combinations of these.

In some embodiments, an additive can be added to the apparatus 10 to aid in ionization and water treatment/purification. In some embodiments the additive can increase the electric conductivity of the water thereby enhancing the killing of bacteria and microorganisms. In some embodiments, the additive can improve the electrocatalytic oxidation effect. In some embodiments, the additive can act as an eletrofloculant to aid in heavy metal removal. Additives that can be used include, for example, ferric chloride, sodium chloride and the like and combinations of these. In embodiments, the additives can ionize in the water, break apart longer organic chains contaminating the water, and precipitate out contaminants. The amount of additive can vary depending upon the level of contamination of the water to be purified/treated and the amount of purification needed, for example less purification can be used for open water sources, while a higher level of purification can be used for drinking water. In some embodiments the amount of additive can be, for example 10 ppm to 500 ppm parts of water.

Cleaning port 20 and discharge port 22 of FIG. 1 can be used to clean the container 12 and reactor unit 24. Gas exhaust port 18 can provide a route of exit for any gasses and foam evolved during the waste water treatment process.

A system 100 is depicted in FIG. 2 for purification of waste water. The system 100 utilizes several apparatuses 110/112/114 in sequence. The apparatuses 110/112/114 are connected to water pipes 140/142 that channel water through the apparatuses 110/112/114 in sequence. Gasses evolved during purification of waste water can exit the apparatuses 110/112/114 through gas exhaust ports 150/152/154, respectively. The gas exhaust ports 150/152/154 can joint at a common exhaust 156 to exit the system 100.

The apparatuses 110/112/114 of the system 100 can be connected in sequence or parallel. Intake of water can be at the top corner of the apparatus 110/112/114 and outflow of the water, at the lower corner of the apparatus 110/112/114. The intake and outflow can be located diagonally from each other to ensure proper flow of water through the system 100. In some embodiments, the apparatuses 110/112/114 are in parallel, in other embodiments, the apparatuses can be stacked.

A system 100 can be constructed using any number of apparatuses 110/112/114. In some embodiments, 1 to 10 apparatuses can form a system 100. In some embodiments, 8 apparatuses can form a system 100.

An embodiment of a system 200 including only one apparatus 210 is depicted in FIG. 3. The apparatus 210 includes a container 212, intake tube 214, outlet tube 216, gas exhaust 218, and spray nozzles 240. A reactor unit 224 is present inside the container 212. The reactor unit 224 includes electrodes 226 having cathodes 230 and anodes 228. Cathodes 230 and anodes 228 are connected to power supply 232. Intake tube 214 is connected to intake pipe 240. The intake pipe 240 can be controlled by pump 260. In use, pump 260 can control the inflow of water through the intake pipe 240 into the container 212. Electrical current from the power supply 232 flows to the electrodes 226, generating hydrogen gas and hydrogen peroxides at the surface of cathodes, and hydroxyl ions and oxygen gas at the surface of the anodes 228 stirring the water.

Spray nozzles 240 can be used to clean dirt off of the electrodes 226. In embodiments, this system 200 can be used in a pond, spa, swimming pool, or other body of water not intended for drinking.

FIG. 4 depicts an embodiment of a system for use in purification or treatment of any type of waste water. In embodiments, the system 300 of FIG. 4 can be used in treatment of drinking water. The system 300 includes an apparatus 310 having a container 312, inlet tube 314, outlet tube 316, gas exhaust 318, cleaning port 320, discharge port 322, and a reactor unit 324. The reactor unit 324 includes electrodes (not shown) and is connected to power control 380 and power control 380 is connected to power supply 332. Power supply 332 and power control 380 can be contained in control unit 334. In some embodiments, control unit 334 can include a current alternator that changes the direction of the current.

Control unit 334 can also include air pump 372. Air pump 372 can pump air into air conduit 370. In some embodiments, air conduit 370 can include one or more holes. In some embodiments, activated carbon can also be added to the air conduit 370 to purify the air. Air pump 372 can pump air through air conduit 370 into container 312 aiding any gases produced in container 312 in exiting through the gas exhaust port 318.

Pump 376 can extract water from reservoir 374 through pipe 340 and inlet tube 314 into the container 312. Valve 388 can be used to control the volume of water flowing into container 312. Water can leave container 312 through outlet tube 316, down pipe 342 and back into reservoir 374. Valve 378 can be used to control the volume of water leaving the container 312.

Gasses generated in container 312 can exit container 312 through gas exhaust 318. When cleaning of the system is needed, cleaning port 320 can be used to add cleaning

solutions and water to container 312. After cleaning discharge port 322 can be used to drain the container 312. Valve 382 can be used to control the volume of water leaving discharge port 322.

In some embodiments, the container 312 can include a cover 384. In some embodiments, the container 312 can be lined with a liner 384. The liner 384 can be, for example, a non-reactive, food safe plastic.

In embodiments, the present disclosure can purify about 1 L of water using about 0.0416 W/h, the water can be purified to level of drinking water purity. Thus, a minimal amount of electricity is needed to purify water using the apparatus of the present disclosure. This reduces cost and use of electricity.

While various aspects and embodiments have been disclosed herein, other aspects and embodiments will be apparent to those skilled in the art. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, within the scope and spirit of the disclosure being indicated by the following claims.

Claims

1. A method of water purification comprising:
exposing a quantity of water to an electrical current in a container, wherein said electrical current is induced by at least two electrodes separated by about 100 mm.
2. The method of claim 1, wherein the step of exposing occurs in the absence of an additive.
3. The method of claim 1, wherein said electrical current is supplied through between 2 and 1200 electrodes.
4. The method of claim 1, further comprising transferring said water from a first container to a second container and exposing said water to additional electrical current in said second container.
5. The method of claim 1, wherein said water is cycled through said container multiple times.
6. The method of claim 1, wherein said electrical current is sufficient to achieve at least one of oxidation of heavy metals, reduction of bacteria, decomposition of ammonia compounds, and decomposition of organic compounds.
7. An apparatus for water purification comprising:
a container;
at least two electrodes; and,
a power supply,
wherein said at least one electrode is located within said container and said at least one electrode is operatively connected to said power supply and said electrodes purify about 1 L of water with about 0.0416 W/h of electricity.
8. The apparatus of claim 7, wherein said apparatus further comprises a gas exhaust port.
9. The apparatus of claim 7, wherein said at least two electrodes are separated by about 100 mm.

10. The apparatus of claim 7, wherein said at least two electrodes each include at least one cathode and at least one anode.
11. The apparatus of claim 10, wherein said at least one cathode includes a coating selected from the group consisting of: metal oxides, porcelain modified oxide, and boron doped diamond.
12. The apparatus of claim 7, wherein each electrode of said at least two electrodes comprises more than one cathode and more than one anode.
13. The apparatus of claim 7, further comprising a cleaning port and a discharge port.
14. The apparatus of claim 7, further comprising an inlet tube and an outlet tube, wherein said inlet tube and said outlet tube are located diagonally from each other in said container.
15. The apparatus of claim 7, further comprising an air pump.
16. The apparatus of claim 7, wherein said at least two electrodes are connected in parallel.
17. The apparatus of claim 7, wherein said at least two electrodes are connected in series.
18. A system for water purification comprising:
 - an apparatus comprising at least one electrode operatively connected to a power supply;
 - a pipe operatively connected to said apparatus;
 - a water source operatively connected to said pipe,
 - wherein said at least two electrodes are separated by about 100 mm.
19. The system of claim 18, further comprising two or more apparatuses connected by said pipe.
20. The system of claim 19, wherein said two or more apparatuses each comprise between 2 and 1200 electrodes connected in series.
21. The system of claim 20, wherein water from said water source flows through said pipe sequentially into said two or more apparatuses.

22. The system of claim 21, wherein the water flows into a container of said apparatus from said pipe at the top of said container and exits said container through said pipe at the bottom of said container.
23. An apparatus for water purification comprising:
a container;
a power supply; and
at least one electrode comprising a cathode and an anode each comprising metal oxide coated titanium,
wherein said cathode and anode are separated by about 2 mm to about 5 mm and wherein said electrodes are located within said container and are operatively connected to said power supply.
24. The apparatus of claim 23, wherein the power supply provides a current density of about 1 A/dm² to about 10 A/dm².
25. An apparatus for water purification comprising:
a container;
a power supply; and
at least one electrode comprising a cathode and an anode each comprising metal oxide coated titanium operatively connected to said power supply,
wherein said cathode and anode are separated by about 0.25 mm to about 1.5 mm and said power supply provides a current density of about 0.1 A/dm² to about 2 A/dm².