

ROTATING FLOW MEMBRANE OXIDATION REACTOR FOR WATER TREATMENT

FIELD OF THE INVENTION

The invention generally relates to an apparatus and method for chemical-mechanical treatment of fluids, and more particularly, to a rotating flow membrane oxidation reactor for treating water suspended with colloidal particles.

BACKGROUND

Water from source such as water from lakes, rivers, streams and reservoirs, or water from water treatment plants that are contaminated due to conditions in the distribution network, or water resulting from industrial processes purified to sewage discharge standards, usually contains suspended solids, organic contaminants, micro-organisms, bacteria and viruses. These are micro-sized or colloidal particles which are very minute and have negligible settling velocities. In order to reduce their concentrations to levels suitable for reverse osmosis, activated carbon absorption, ion exchange, or processes which require water with low impurity levels, a combination of chemical and mechanical treatment methods is required.

Conventional water treatment systems for treating water suspended with colloidal particles, consist of a process train involving mainly coagulation, flocculation, sedimentation, filtration and disinfection.

These processes are carried out in separate units as illustrated in Figure 1. The coagulation unit 100 is normally a mixing tank 110 where a coagulant 120 is rapidly assimilated into the water by means of a turbine 130. The purpose of the coagulant 120 is to induce agglomeration of the suspended colloidal particles into flocs. The water that is coagulated 130 then enters the flocculation unit 200 where it is gently stirred by means of paddles 210. The gentle stirring action facilitates inter-particle contact and promotes agglomeration and growth of the flocs to sizes that can be removed

by sedimentation and filtration. In the sedimentation unit 300, the flocs settle and discharge as sludge 310 leaving behind clarified water 320. The clarified water 320 then advances to the filtration unit 400. Thereafter, the water that is filtered 410 is passed through the disinfection unit 500 thereby completing the water treatment process to form effluent 510.

As can be seen, the conventional water treatment system can be time consuming as the processes are carried out in sequence and retention time in each of the treatment units, in particular flocculation, sedimentation and filtration, is rather high. In order to compromise between flow rate and retention time, size of the treatment units is usually very large. A considerable amount of land area would thus be required to accommodate the water treatment system.

Therefore, a need exists to provide a waste water treatment system that is time efficient and compact in size.

SUMMARY

An aspect of the invention provides an apparatus for purifying water with colloidal particles entrained therein. The apparatus comprises a first vessel for clarifying the water, the first vessel comprising an inlet means for the fluid to enter into the first vessel and a means for inducing flocculation and sedimentation of the colloidal particles in the water within the first vessel to form clarified water. The apparatus also comprises a second vessel in fluid communication with the first vessel, comprising a filter for filtering the clarified water, a means for disinfecting the clarified water, the clarified water passing through the filter and means for disinfecting to treat the clarified water into purified water, and an outlet means for the purified water to exit the apparatus. The filter is preferably a membrane filter.

According to another aspect of the invention, the means for inducing flocculation and sedimentation is a cyclone mechanism configured to produce a hydraulic rotating flow motion in the water.

According to yet another aspect, the means for disinfecting comprises photocatalysts and a UV radiation source.

In an aspect of the invention, the means for disinfecting further comprises a porous support.

In another aspect of the invention, the photocatalyst is a semiconductor photocatalyst.

In still another aspect of the invention, there is provided a method for treating water suspended with colloidal particles, comprising the steps of mixing a coagulant with the water and inducing a hydraulic rotating flow motion in the water that is coagulated to achieve flocculation and sedimentation to form clarified water. The method further comprises filtering the clarified water to form a filtrate. The method also further comprises disinfecting and polishing the filtrate to form purified water.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features, objects and advantages of embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, in conjunction with drawings, in which:

Figure 1 shows a conventional water treatment system comprising coagulation, flocculation, sedimentation, filtration and disinfection units;

Figure 2 shows a cross-sectional view of an apparatus for treating water in accordance with an embodiment of the invention;

Figure 3 shows a plan view of the apparatus in accordance with an embodiment of the invention;

Figure 4 depicts how flocculation and sedimentation are achieved by a cyclone mechanism in accordance with an embodiment of the present invention;

Figure 5 depicts membrane filtration and photocatalytic oxidation in the inner core of the apparatus in accordance with an embodiment of the invention.

Figure 6 illustrates another embodiment of the invention.

DETAILED DESCRIPTION

An embodiment of the invention, a rotating flow membrane oxidation reactor 1, as shown in Figures 2 and 3 and method of an embodiment is described herein with reference to Figures 4 and 5, provides an apparatus 1 for the treatment of water to remove colloidal particles such as suspended solids, organic matter, micro-organisms, bacteria and viruses entrained therein.

With reference to Figures 2 and 3, an apparatus 1 for treating water, in particular water suspended with colloidal particles or micro-sized solids. The apparatus 1 has a first vessel 30 having a first wall 32 and a sloping base 34. Connected to the first wall 32 is an inlet means 20 which comprises a coagulant inlet 24 and a water inlet 22, both connected to an inlet duct 26. Water 10 from the water inlet 22 is mixed with adequate amounts of coagulant 11 from the coagulant inlet 24 to form a coagulated fluid 12 prior to entry into the outer core 2. The coagulated fluid 12 enters the outer core 2 via the inlet duct 26. Installed to the sloping base 34, is means for sludge removal which can be a sludge dispensing channel and valve system 62.

Disposed vertically within the primary vessel 30, is a second vessel 40 having a second wall. The second vessel 40 houses a membrane photocatalytic oxidation reactor 42. The membrane photocatalytic oxidation reactor 42 consists of a membrane filter 46 with a cavity 45, a porous support 48 within the cavity 45 having a hollow core 47, photocatalysts coated onto the porous support 48, and a tubular UV lamp 49 within the hollow core 47 of the porous support 48. An outlet means 60 is connected to the second vessel 40 and a cover 36 is placed on top of the first vessel 30.

The area between the first wall 32 of the first vessel 30 and the second wall 44 of the second vessel 40 defines the outer core 2, while the area within the second vessel 40 defines the inner core 4. Flocculation and sedimentation are carried out concurrently in the outer core 2 to remove mainly the suspended solids. Membrane filtration and photocatalytic oxidation are carried out in the inner core 4 to effect removal of suspended solids, micro-organisms, bacteria, viruses and organic matter.

A cyclone mechanism 50 comprising a pump unit 52, a suction unit 56 and an expulsion unit 54 is fixed onto the first wall 32 of the first vessel 30.

In operation, with reference to Figure 4, flocculation and sedimentation occurring in the outer core 2 are shown in accordance with an embodiment of the invention.

Prior to flocculation and sedimentation processes in outer core 2, the water 10 is mixed with a coagulant 11. The coagulant 11 chemically modifies the colloidal particles present in the water 10 and destabilises them. This results in the particles developing a tendency to aggregate to form flocs 13.

To optimise the floc 13 formation process so that maximal turbidity can be removed, the coagulated fluid 12 has to be gently stirred to encourage inter-particle contact and to promote agglomeration of particles into flocs 13 of sizes that can be removed by sedimentation and filtration. This process is flocculation. The gentle stirring action can be provided by inducing a hydraulic laminar flow motion in the water. This is achieved by means of the cyclone mechanism 50 of the invention. The cyclone mechanism 50 creates the rotating laminar flow pattern by drawing in water through the suction unit 56 and expelling the water in a spiral direction along the first wall 32 of the first vessel 30 through the expulsion unit 54. The suction and expulsion actions of the units are powered by the pump unit 52.

The hydraulic rotating flow can also be created by means of an inlet configured to introduce the water in a spiral direction along the first wall 32 of the outer vessel 30.

The position of fixture for the cyclone mechanism 50 is not limited to the first wall 32 and can be fixed onto the second wall 44 or other parts of the apparatus 1 where it can create the laminar rotating flow motion.

In addition to facilitating flocculation, the cyclone mechanism 50 also accelerates sedimentation of the flocs 13. The hydraulic rotating flow motion induced by the cyclone mechanism 50 creates a vortex with an outermost radius in contact with the first wall 32 and an innermost radius in contact with the second wall 44. Sedimentation is accelerated by means of a centrifugal force which directs the flocs 13 radially to the outermost radius of the vortex where they sediment and accumulate as sludge 14 at the sloping base 34.

Periodically, the sludge is drained off by means of the sludge dispensing channel and valve system 62. Fluid that remains in the outer core after sedimentation is known as clarified fluid 15. The centrifugal force also results in the clarified fluid 15 moving towards the innermost radius of the vortex and towards the second wall 44.

In operation, with reference to Figure 5, membrane filtration and photocatalytic oxidation occurring in the inner core 4 are shown in accordance with an embodiment of the invention.

The clarified fluid 15 overflows from the outer core 2 into the inner core 4 via the second wall 44 of the second vessel 40, which acts as an overflow panel. Here, the clarified fluid 15 will enter the membrane photocatalytic oxidation reactor 42 through a membrane filter 46. The clarified fluid 15 is passed through the membrane filter 46 by means of a suction pressure applied at the outlet means 60. This constitutes membrane filtration. Fluid resulting from the filtration process is known as a filtrate 16.

Membrane filters can be ceramic or polymeric type membranes. Depending on the required effluent quality, membranes can be fabricated to the required pore sizes to achieve the desired degree of particle separation. The ceramic membrane is preferred for easy maintenance and handling.

After some time, it is inevitable that the membrane filter 46 will encounter fouling and has to be back-washed before they can be used again.

The membrane photocatalytic oxidation reactor 42 is designed such that the membranes can be dismantled and taken out of the inner core 4 and replaced.

After membrane filtration, the filtrate 16 undergoes a final stage of treatment which is photocatalytic oxidation in the presence of photocatalysts and UV radiation. Photocatalysts are bonded onto a porous support 48 made of porous base materials such as iron oxide, silica or zinc oxide. The catalyst can be any semiconductor photocatalyst such as CdS and TiO_2 . The catalyst-coated porous support 48 and the UV tubular lamp 49 are arranged in a concentric manner such that the UV tubular lamp 49 is disposed within the cavity 45 of the porous support 48. In addition, the support 48 also acts as an absorbent for organic and inorganic pollutants in the filtrate 16.

Upon activation by UV radiation, the photocatalyst causes oxidative degradation of organic contaminants and micro-organism species that are present in the filtrate into CO_2 , H_2O and mineral acids. This process is known as photocatalytic oxidation.

Most laboratory reactions involving photocatalytic oxidation reactions require forming a suspension of particulate photocatalysts in a fluid medium containing organic pollutants. However, this procedure is impracticable for commercial purification of water as the catalysts would have to be removed before the water can be used. The photocatalyst are extremely small in size and would either be impossible or prohibitively expensive to remove. This problem is addressed in an embodiment by firmly bonding the photocatalyst onto a support which can also double up as an absorbent for organic and inorganic pollutants.

Upon completion of the photocatalytic oxidation reaction, a resulting treated water 18 exits via the outlet means 60 and into a storage tank (not shown in the figures) where it is stored for future use.

The treatment of water can be carried out in a continuous, semi-continuous or batch mode, depending on the specifics of the waste water being treated.

Another embodiment of the present invention is depicted in Figure 6. A plurality of membrane oxidation reactors 42 is housed in the second vessel 44. The number of membrane oxidation reactors 42 that the second vessel can house is in the range of 3 to 8.

The apparatus 1 of the embodiments of the invention may be used for the treatment of water from source such as water from lakes, rivers, streams, reservoirs, etc., and water from water treatment plants that are contaminated due to conditions in the distribution network. It can also be used in the pre-treatment of seawater and wastewater prior to reverse osmosis, activated carbon absorption, ion exchange and processes which require water with low impurity levels.

To accommodate a larger treatment capacity, the apparatus 1 can be scaled up in size or a few apparatus 1 can be arranged in series or on top of one another.

An advantage of an embodiment of the invention is that it integrates the water treatment processes of coagulation, flocculation, sedimentation, membrane filtration and photocatalytic oxidation into a single stand alone reactor thereby saving on land area that is required.

Another advantage of an embodiment of the invention is that it shortens the time spent on treating waste water by enabling flocculation and sedimentation to occur concurrently.

Yet another advantage of an embodiment of this process is that the photocatalytic process does not generate sludge but only harmless by-products such as CO_2 , H_2O and mineral acids. In comparison, the conventional method of disinfection such as chlorination results in the generation of sludge as a by-product which is expensive to treat.

It will be appreciated that the invention is not limited to the embodiments described herein and additional embodiments or various modifications may be derived from the application of the invention by a person skilled in the art without departing from the scope of the invention.

The figures 7 to 10 disclose the following:

- A: Circular wall introduced into the outer core to lengthen the flow path of the fluid
- B: Device for the introduction of water to be treated and the treatment chemicals. The device also performs the role of turbulent mixing between the water to be treated and the treatment chemicals by hydraulic means.
- C: Device B outlet that is configured to impart a outlet water trajectory that will cause a circular hydraulic fluid flow in the outer core
- D: Point where water to be treated is introduced
- E: Point where chemicals for pH adjustment and coagulation (Alum, Iron Sulphate, Lime) is added
- F: Point where polymers are added to aid in coagulation and flocculation
- G: Modifications to the inner core. Sloping base to aid in the settlement and discharge of the sludge that is present in the inner core
- H: Sludge discharge point of the inner core and outer core. (manual or electronically controlled.)
- I: Optionally, mesh netting or similar device to enable improved flocculation and faster settlement of the floc particles. This device is placed at the region of the outer core where the rotating hydraulic flow is fast
- J: Also optionally, the UV lamp and photocatalyst in the membrane can be substituted with some other media that performs the role of further polishing the water. (ie. Activated carbon, ion exchange resins etc..)
- K: The UV/photocatalyst can also optionally be placed as a separate unit or attached at the side of the outer core.
- L: L shows the circular hydraulic flow velocity that Device C imparts.
- M: The circular hydraulic flow velocity reduces as the water travels downward
- N: Point where the water flow under device A
- O: Water overflows into the inner core where the membrane is located

Advantages over conventional (Figure 1) treatment

1. Integrated system to take over entire water treatment process. (coagulation, rapid mixing, slow mixing, flocculation, sedimentation and disinfection)
2. Smaller area requirement and reduce civil works requirement
3. Mobility of system. (System can be dismantled and set up at a different location speedily)
4. The system replaces mechanical mixing with hydraulic mixing (less costly and less maintenance)
5. Circular hydraulic flow in outer core increases the travel time of the flocs particles compared to conventional rectangular sedimentation tank of much larger size.
6. The system can be configured for different kinds of water disinfection and polishing.
7. The system can be configured to use different kinds of membranes.

CLAIMS

1. An apparatus for purifying water comprising:
 - a first vessel for clarifying the water, the first vessel comprising:
 - an inlet means for the water to enter into the first vessel; and
 - a means for inducing flocculation and sedimentation of the colloidal particles in the water within the first vessel to form clarified water; and
 - a second vessel in fluid communication with the first vessel, comprising:
 - a filter for filtering the clarified water;
 - a means for disinfecting the clarified water, the clarified water passing through the filter and means for disinfecting to treat the clarified water into purified water; and
 - an outlet means for the purified water to exit the apparatus.
2. An apparatus according to claim 1, wherein the means for inducing flocculation and sedimentation comprises a cyclone mechanism configured to produce a hydraulic rotating flow motion in the water.
3. An apparatus according to claim 1 or 2, wherein the filter comprises a cavity and the means for disinfecting is arranged within the cavity.
4. The apparatus according to any one of the preceding claims, wherein the means for disinfecting comprises:
 - a photocatalyst; and
 - a UV radiation source, subjecting the water through photocatalytic oxidation in the presence of UV radiation in the presence of the photocatalyst and the UV radiation source.
5. An apparatus according to any one of the preceding claims, wherein the means for disinfecting further comprises a porous support.

6. An apparatus according to any one of the preceding claims, wherein the filter is a membrane filter.
7. An apparatus according to any one of the preceding claims, wherein the outlet means further comprises a suction pump to facilitate flow of the water within the apparatus.
8. An apparatus according to any one of the preceding claims, wherein the inlet means comprises a water inlet and a coagulant inlet.
9. An apparatus according to claim 6, wherein the membrane filter is a ceramic membrane.
10. An apparatus according to claim 8, wherein the water inlet and the coagulant inlet are connected to a main duct affixed to the first vessel.
11. An apparatus according to claim 5, wherein the porous support is made from a porous base material selected from the group consisting of iron oxide, silica and zinc oxide.
12. An apparatus according to claim 4, wherein the UV radiation source is a tubular UV lamp.
13. An apparatus according to claim 4 or 12, wherein the photocatalyst is a semiconductor photocatalyst.
14. An apparatus according to claim 4, 12 or 13, wherein the photocatalyst is CdS.
15. An apparatus according to claim 4, 12 or 13, wherein the photocatalyst is TiO_2 .

15. Photocatalyst as described in SG patent application 200406822-7
16. A method for treating water suspended with colloidal particles, comprising:
 - mixing a coagulant with the water; and
 - inducing a hydraulic rotating flow motion in the water that is coagulated to achieve flocculation and sedimentation to form clarified water.
17. A method according to claim 16, further comprising filtering the clarified water to form a filtrate.
18. A method according to claim 16 or 17, further comprising disinfecting the filtrate to form purified water
19. A method according to any one of claim 16 to 18, wherein the hydraulic rotating flow motion is induced by a cyclone mechanism.
20. A method according to claim 17, wherein filtering the water involves passing the waste water through a membrane filter.
21. A method according to claim 18, wherein disinfecting the water involves subjecting the waste water through photocatalytic oxidation reaction in the presence of photocatalysts and UV radiation.
22. Further polishing of water can be achieved by adsorption and ion-exchange using different media.