

FILTER DEVICES AND FILTERING METHODS

Cross-reference to Related Applications

[0001] The present application claims the benefit of the Singapore patent application No. 10201400583S filed on 12 March 2014, the entire contents of which are incorporated herein by reference for all purposes.

Technical Field

[0002] Embodiments relate generally to filter devices and filtering methods.

Background

[0003] Ballast water treatment is an important task in various applications. Thus, there may be a need for an efficient way for ballast water treatment.

[0004] Ships may use ballast water to provide stability and maneuverability during a voyage. Water may be taken on at one port when cargo is unloaded and may usually be discharged at another port when the ship receives cargo. When uploading ballast water, organisms in seawater may be carried into ballast tanks and discharged to the destination sea area when downloading. Bringing ballast water in ships from one sea area to another may cause the invasion of harmful aquatic organisms and pathogens. Unregulated ballast water discharging may cause serious ecological, economic and public health impact to the receiving environment. The invasion of alien organisms had been listed by Global Environmental Facility (GEF) as one of the four hazards to the ocean.

[0005] In order to control the invasion of harmful aquatic organisms and pathogens in ballast water effectively, the International Maritime Organization (IMO) initiated the International Convention and Management of Ship's Ballast Water and Sediments in 2004. The convention requires that new ships must install ballast water treatment systems and this requirement is also applicable to existing ships. The convention had set regulation D-2 which regulates the category and the quantity of the surviving organisms in treated ballast water.

[0006] Table 1 shows a schedule for Installation of Ballast Water Treatment System, wherein D-1 is a ballast water exchange standard, and D-2 is a ballast water treatment standard.

Ship Type	Year of ship Building	Ballast Capacity, m ³	Performance Standard	Implement Date
Existing Ships	<2009	<1500	D-1/D-2	≤2016
			D-2	2017
		1500-5000	D-1/D-2	≤2014
			D-2	2015
		>5000	D-1/D-2	≤2016
			D-2	2017
New Ships	≥2009	<5000	D-2	2009
	2009-2011	≥5000	D-1/D-2	≤2016
			D-2	2017
	≥2012	≥5000	D-2	2012

Table 1.

[0007] Table 2 shows IMO D-2 standards for discharge of ballast water.

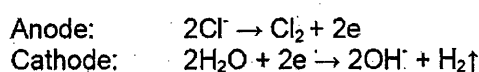
Organism Type	Required Regulation
Organisms, $\geq 50\mu\text{m}$ minimum dimension	$<10\text{cells}/\text{m}^3$
Organisms, $<50\mu\text{m}$ and $\geq 10\mu\text{m}$ minimum dimension	$<10\text{cells}/\text{ml}$
Toxicogenic <i>Vibrio cholerae</i> (serotypes O1 and O39)	$<1\text{cfu}/100\text{ml}$, or $<1\text{cfu}/\text{g}$ (wet weight) of zooplankton samples
<i>Escherichia coli</i>	$<250\text{cfu}/100\text{ml}$
Intestinal Enterococci	$<100\text{cfu}/100\text{ml}$

Table 2.

[0008] To meet the requirement of the Convention, various technologies are provided all over the world for treatment and management of ballast waters. Commonly used technologies include: electro-chlorination; UV radiation and filtration; ozonation; biocide addition; electro-oxidation; electro-coagulation; de-oxygenation; cavitation; and coagulation and magnetic separation.

[0009] Among them, the ballast water treatment systems based on electrolytic disinfection may be most widely adopted in many commercial systems. The systems based on electrolytic disinfection usually consist of two major functional units, mechanical filters and electrolyzer, for filtration and electro-chlorination, respectively. When seawater flows through the electrolyzer, decomposition reactions take place on the electrode surfaces, with chlorine produced at the anode and hydrogen gas at the cathode.

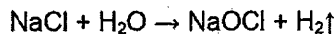
The reaction principle is as follows:



[0010] Chlorine gas can be dissolved in water to produce hypochlorous acid and hydrochloric acid rapidly:



[0011] So the whole reaction is:



[0012] The electrochlorination processes may be effective for both viral and bacterial inactivation. Various related studies have focused on the electrochemical generation of active chlorine species or electro-chlorination. The advantages of the electrolytic-based ballast water treatment system include in-situ biocide generation, flexible footprint, low energy consumption, and viability for automation.

[0013] Major functions of the filters in ballast water treatment system are to remove or break larger organisms using $\sim 40 \mu\text{m}$ weave wire screen. Use of the large sized filter may have advantages of higher flux, lower transmembrane pressure, less fouling and clogging. However, the large size also allow for large amount of organisms sized less than $40 \mu\text{m}$ to pass through the filter and impose high loading for later treatment. Even though the large sized filter is used, normally backwash is still required to clean the filter frequently, leading to lower productivity and high operation cost. How to realize effective filtration with fine filters has been a challenge to the equipment makers.

[0014] One solution may be to make the filter with thin film membrane with straight cylindrical pores, identical pore sizes and arbitrary shape as well as high porosity, which has been realized by using micro-fabrication technology. The advances in microfabrication processes may allow enough flexibility to control the porosity and the pore size and shape according to application requirements. Various micro-fabrication techniques may be provided to create membranes with the cylindrical pores like laser interference lithography and silicon micro machining technology, aperture array

lithography, nano-imprinting using alumina template, excimer laser, phase separation micromolding, and more recently dissolving mold technique.

[0015] Materials-wise, metal sieves or meshes may be advantageous over the polymer or silicon based membranes due to their better mechanical, thermal and chemical stabilities. Metal sieves may be fabricated by photo electroforming process, in which Si or glass substrate is metalized by vapor deposition, followed by photolithographic patterning and selective electroforming. Applications of the metal thin film membranes for solid/liquid separation may be provided. Although high performance metallic membranes may be provided and used for various separation processes, the flux may be declined with operation and frequent backwashing is still needed to remove the particles stick on to it, especially when finer micro-sized membranes are used.

[0016] In addition, a combination of the two components of the system, filter and electrochemical cell may be provided, for example two Pt wire electrodes may be provided on a plastic membrane to detect microbial on the filter (J.R. Wilkins et al., 1980).

[0017] A combined filtration-electrochemical detector may include a retainer ring, a $0.45\mu\text{m}$ filter, platinum electrodes, absorbent pads, and a petri dish, and leads to a strip-chart recorder.

[0018] An electrochemical carbon nanotube filter, which is dual-functional, i.e. filtration and electro-oxidation may be used. In this device, the filter may be fabricated by dispersing carbon nanotubes onto a Teflon membrane with $5\mu\text{m}$ pores, which acts as an anode. The cathode may be stainless steel ring. It will be understood that the adhesion of nanotubes to the Teflon membrane supporter may be very weak and back-flushing may

not be allowed, otherwise, the nanotubes may be flushed away. In addition, the Teflon membrane may be very expensive. Furthermore, such an electrochemical filter may be used only in dead-end filtration mode. However, for high flux filtration processes the cross-flow filtration mode may be applied.

[0019] An electrochemical MWNT (multi-walled nanotubes) filter may be used (C.D. Vecitis et al., 2011). A perforated stainless steel cathode, an insulating seal, an anodic titanium ring connector to the MWNT, and an anodic MWNT filter may be used. A modified upper piece of the Millipore filtration apparatus with anodic and cathodic connectors. An upper piece of the filtration apparatus may include a perforated stainless steel cathode. The MWNT filter may include 3 mg MWNTs (0.31 mg/cm² coverage) on a Teflon membrane (5 μ m pore size) on bottom piece of apparatus.

[0020] A membrane-electrode assembly may be used mainly for producing ozone water (US2013/0032491A1), and such a membrane-electrode assembly by electrochemical process may include an anode plate with pores (Nb), BDD coating, and a cathode plate with pores (SS, stainless steel).

[0021] In such a filter assembly, the anode may be BDD (boron doped diamond) coated Nb metal sheet with 1-5 mm sized through pores and the cathode may be a stainless steel sheet with 1-5 mm sized through pores. In between the two electrodes a polymeric membrane may be provided as solid electrolyte. The large through pores on the electrodes may be the water flow paths without filtration function. Even the hole size may be reduced down to 0.1 mm at high cost, the function of the membrane assembly is ozone generation.

[0022] Limitations of the current technologies related to ballast water treatment and other filtration applications are summarized as below:

[0023] a) The filters used in a ballast water treatment system is with large pore sized (about 40 μm) wave type cartridge, and allows for particles or micro organisms to pass through, leading to high loading for the following electrochemical treatment and therefore high energy consumption.

[0024] b) The conventional filters are prone to fouling and clogging problems in the operation, leading to rising pressure to kept a constant flux and therefore high power consumption.

[0025] c) To mitigate the fouling and clogging problems, the conventional filters need frequent backwashing with clean water, leading to high operation cost due to down time, clean water and power consumption.

[0026] d) The lifetime of conventional filters could be short due to materials incompatibility with the highly erosive and corrosive environments in sea water, leading to the cost caused by filter cartridge replacement and down time.

[0027] e) Conventional electrochemical ballast water treatment systems consist of filter and electrochemical device (in other words: unit) which are assembled separately and operate independently, leading to large space occupation and high fabrication cost.

[0028] f) Electro-filter designs consisting of a Teflon membrane as a support of the conductive carbon-nanotubes layer are expensive, low strength, as well as low flux.

Summary

[0029] According to various embodiments, a filter device may be provided. The filter device may include: an anode; and a cathode provided at least substantially in parallel to the anode. At least one of the anode and the cathode may include (or may be or may be included in) a sieve.

[0030] According to various embodiments, a filtering method may be provided. The filtering method may include: providing a fluid flow through a filter device including an anode and a cathode provided at least substantially in parallel to the anode, wherein at least one of the anode or the cathode may include (or may be or may be included in) a sieve.

Brief Description of the Drawings

[0031] In the drawings, like reference characters generally refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention. In the following description, various embodiments are described with reference to the following drawings, in which:

FIG. 1A shows a filter device according to various embodiments;

FIG. 1B shows a filter device according to various embodiments;

FIG. 1C shows a flow diagram illustrating a filtering method according to various embodiments;

FIG. 2 shows a schematic illustration of a screen filter assembly according to various embodiments;

FIG. 3 shows an illustration 600 of oxidant generation on an anode surface;

FIG. 4 shows a schematic diagram of hydrogen gas generation for sieve self-cleaning and oil separation;

FIG. 5A shows a schematic illustration of a multi-functional screen filter device having inner anode grid 804 and an outer cathode sieve according to various embodiments;

FIG. 5B shows an illustration of a liquid flow in a cross-flow filtration mode according to various embodiments;

FIG. 6A shows a schematic illustration of a multi-functional screen filter device according to various embodiments, having an inner cathode sieve and outer anode lined on filter support;

FIG. 6B shows an illustration of a liquid flow in a cross-flow filtration mode according to various embodiments;

FIG. 7A shows a schematic illustration of a multi-functional screen filter device having an inner anode grid and outer cathode sieve according to various embodiments;

FIG. 7B shows an illustration of a liquid flow in a cross-flow filtration mode according to various embodiments;

FIG. 8A shows a schematic illustration of a multi-functional screen filter device having an inner anode rod/bar and an outer cathode sieve according to various embodiments; and

FIG. 8B shows an illustration of a liquid flow in a cross-flow filtration mode according to various embodiments.

Description

[0032] Embodiments described below in context of the devices are analogously valid for the respective methods, and vice versa. Furthermore, it will be understood that the embodiments described below may be combined, for example, a part of one embodiment may be combined with a part of another embodiment.

[0033] It will be understood that an influent may also be referred to as an inlet. And effluent may also be referred to as an outlet. Furthermore, it will be understood that influent and effluent may not only refer to the portion by which material is provided or exhausted, but also to the material itself.

[0034] According to various embodiments, the problems of the conventional methods may be solved with a compact screen filter device including a catalytic metallic sieve cathode and a catalytic anode to integrate multi-functions, such as particle/liquid separation, oxidant production, filter self-cleaning, as well as electro-floatation.

[0035] Various embodiments may be provided for an efficient way for ballast water treatment.

[0036] Various embodiments relate to a new design for ballast water treatment combining the electrochlorination and electro-oxidation processes with effective filtration by using metal sieve membranes, effective in a sense of high throughput and back-wash free operation. Various embodiments may be applied to (but are not limited to) ballast

water treatment. Various embodiments may find applications where both filtration and electrochemical generation of oxidant species are required.

[0037] According to various embodiments, a multi-functional screen filter device may be provided.

[0038] Various embodiments relate to a multi-functional screen filter device integrating particle/liquid separation, oxidant production, electro-floatation, and sieve self-cleaning.

[0039] FIG. 1A shows a filter device 400 (for example electromechanical filter device or electrochemical filter device) according to various embodiments. The filter device 400 may include an anode 402. The filter device 400 may further include a cathode 404. The cathode 404 may be provided at least substantially in parallel to the anode 402 (for example the distance between the anode 402 and the cathode 404 may be at least substantially constant across the whole areas of the anode and the cathode). At least one of the anode 402 or the cathode 404 may include or may be or may be included in a sieve. The anode 402 and the cathode 404 may be coupled with each other, like indicated by line 406, for example using ionic conductive medium or electrolytes.

[0040] In other words, a filter device may be provided which may provide mechanical filtering using a sieve (for example a cylindrical sieve), wherein the sieve at the same time may be provided as a cathode or as an anode.

[0041] According to various embodiments, the cathode 404 may include or may be or may be included in a cathode sieve.

[0042] According to various embodiments, the anode 402 may be has at least substantially a shape of a cylinder.

[0043] According to various embodiments, the anode 402 may include or may be an anode grid (in other words: a grid anode; in other words: an anode in the shape of a grid).

[0044] According to various embodiments, a diameter of the cylinder of the cathode 404 may be larger than a diameter of the cylinder of the anode 402. According to various embodiments, the anode 402 may be provided at least substantially (or at least partially) in the cylinder of the cathode 404.

[0045] According to various embodiments, a diameter of the cylinder of the cathode 404 may be smaller than a diameter of the cylinder of the anode 402. According to various embodiments, the cathode 404 may be provided at least substantially (or at least partially) in the cylinder of the anode 402.

[0046] FIG. 1B shows a filter device 408 (for example electromechanical filter device or electrochemical filter device) according to various embodiments. The filter device 408 may, similar to the filter device 400 of FIG. 1A, include an anode 402. The filter device 408 may, similar to the filter device 400 of FIG. 1A, further include a cathode sieve 404. The cathode sieve 404 may have at least substantially a shape of a cylinder. The filter device 408 may further include a housing 410, like will be described in more detail below. The filter device 408 may further include an inlet 412, like will be described in more detail below. The filter device 408 may further include an outlet 414, like will be described in more detail below. The filter device 408 may further include an insulating layer 415, like will be described in more detail below. The anode 402, the cathode sieve 404, the housing 410, the inlet 412, the outlet 414, and the insulating layer 415 may be coupled with each other, like indicated by lines 416, for example using ionic conductive medium or electrolytes.

[0047] According to various embodiments, the insulating layer 415 may be provided between the anode 402 and the cathode 404.

[0048] According to various embodiments, the insulating layer 415 may include or may be or may be included in an insulating spacer grid layer.

[0049] According to various embodiments, the housing 410 may include an inside wall. According to various embodiments, the cathode 404 may be provided inside the housing 410. According to various embodiments, the anode 402 may be lined onto the inside wall (of the housing 410).

[0050] According to various embodiments, the anode 402 may have at least substantially a shape of a rod.

[0051] According to various embodiments, the filter device 408 may at least substantially be rotationally symmetric with respect to a symmetry axis of the cylinder of the cathode 404.

[0052] According to various embodiments, the inlet 412 may be connected to an internal area of the cylinder of the cathode 404. According to various embodiments, the outlet 414 may be connected to an external area of the cylinder of the cathode 412.

[0053] According to various embodiments, the inlet 412 may be connected to an external area of the cylinder of the cathode 404. According to various embodiments, the outlet 414 may be connected to an internal area of the cylinder of the cathode 404.

[0054] FIG. 1C shows a flow diagram 418 illustrating a filtering method. In 420, a fluid flow through a filter device may be provided. The filter device may include an anode and a cathode provided at least substantially in parallel to the anode. At least one of the anode 402 or the cathode 404 may include or may be or may be included in a sieve.

[0055] According to various embodiments, the cathode 404 may include or may be or may be included in a cathode sieve.

[0056] According to various embodiments, the anode 402 may have at least substantially a shape of a cylinder.

[0057] According to various embodiments, the anode may include or may be an anode grid.

[0058] According to various embodiments, the anode may have at least substantially the same shape with the cathode.

[0059] According to various embodiments, a diameter of the cylinder of the cathode may be larger than a diameter of the cylinder of the anode. According to various embodiments, the anode may be provided at least substantially (or at least partially) in the cylinder of the cathode.

[0060] According to various embodiments, a diameter of the cylinder of the cathode may be smaller than a diameter of the cylinder of the anode. According to various embodiments, the cathode may be provided at least substantially (or at least partially) in the cylinder of the anode.

[0061] According to various embodiments, the filter device may further include an insulating layer provided between the anode and the cathode.

[0062] According to various embodiments, the insulating layer may include or may be or may be included in an insulating spacer grid layer.

[0063] According to various embodiments, the filter device may further include a housing. The housing may include an inside wall. The cathode may be provided inside the housing. The anode may be lined onto the inside wall.

[0064] According to various embodiments, the anode may have at least substantially a shape of a rod.

[0065] According to various embodiments, the filter device may at least substantially be rotationally symmetric with respect to a symmetry axis of the cylinder of the cathode.

[0066] According to various embodiments, providing the fluid flow through the filter device may include or may be providing an inflow to an internal area of the cylinder of the cathode and providing an outflow from an external area of the cylinder of the cathode.

[0067] According to various embodiments, providing the fluid flow through the filter device may include or may be providing an inflow to an external area of the cylinder of the cathode and providing an outflow from an internal area of the cylinder of the cathode.

[0068] The compact screen filter device according to various embodiments may include an anode-cathode assembly, as shown in FIG. 2.

[0069] FIG. 2 shows a schematic illustration 500 of a screen filter assembly according to various embodiments, including an anode 504 and cathode 502 (for example a cathode sieve) separate large particles from solid-liquid mixture. In the anode-cathode assembly of FIG. 2, the anode 504 and the cathode 502 may be spaced by one or more insulate spacers 506 and fixed in parallel such that an electrolytic cell is formed in presence of sea water or electrolyte. The anode-cathode gap may be controlled in the range of 5-50 mm, preferably 10-20 mm. Sea water or electrolyte may be provided in a feed 508 to the cell, and filtrate 510 may be exhausted from the cell.

[0070] According to various embodiments, the cathode may be made of conductive sieve such that the larger particles than the sieve pore size are blocked to pass through the cathode sieve, fulfilling the filter role in a filtration process. The pore size of the cathode

sieve may be desirable from 0.1 to 100 μm , depending on the requirement for the quality of the filtrate.

[0071] According to various embodiments, the electrochemical process may take place during filtration so that oxidants are formed on the anode surface in the filtrate, which are biocides for micro-organism control. The oxidants include but are not limited to Cl_2 and O_3 , as shown in FIG. 3, depending on the type of liquid electrolyte.

[0072] FIG. 3 shows an illustration 600 of oxidant generation on an anode surface with Cl_2 (left side 602 of FIG. 3) and O_3 (right side 604 of FIG. 3).

[0073] According to various embodiments, gas bubbles, for example hydrogen, may be released from the cathode sieve surface, which may repel the tiny particles away to make the sieve surface clean (which may provide self- anti-clogging and anti-fouling), as well as absorb onto the particle surface for floatation to separate oil from oily water, as shown in FIG. 4.

[0074] FIG. 4 shows a schematic diagram 700 of hydrogen gas generation for sieve self-cleaning and oil separation from oily water by floatation effect. In the left portion 702 of FIG. 4, hydrogen gas generation is illustrated. In a middle portion 704 of FIG. 4, gas bubbling, which may provide anti-fouling and anti-clogging, and provision of an influent 706 is illustrated. In a right portion 704, electro-floatation, which may provide oil-water separation, is illustrated.

[0075] According to various embodiments, the anode may be in the forms of but not limited to solid sheets, porous sheets, and meshes. The anode materials may have good electric conductivity and catalytic property for generation of oxidants with high efficiency. The materials having high oxygen evolution potential may be used, which

include but not limited to doped-diamond, PbO_2 , doped- SnO_2 , and the like. In most cases, the anode materials are deposited onto a conductive support such as doped Si, Ta, Ti, Ni, etc., by various coating processes such as PVD (physical vapour deposition), CVD (chemical vapour deposition), chemical deposition, electrolytic deposition, etc.

[0076] According to various embodiments, the cathode may be in porous form, for example, (thin film) metal sieves for the applications of the present invention to separate solid particles from solid-liquid mixture. One example of such technologies for producing thin film metal sieves is selective plating on pre-fabricated template. The cathode materials may have good electric conductivity and catalytic property for generation of hydrogen gas bubbles with high efficiency. The materials having low hydrogen evolution potential may be used, which include but not limited to Pd, Pt, Ni, etc. Ni and Ni alloys may be used because of low cost and easy deposition by chemical and electrolytic processes.

[0077] FIG. 5A shows a schematic illustration 800 of a multi-functional screen filter device having inner anode grid 804 and an inner cathode sieve 802 according to various embodiments.

[0078] FIG. 5B shows an illustration 816 of a liquid flow in a cross-flow filtration mode according to various embodiments.

[0079] According to various embodiments, a multi-functional screen filter device design may be provided, including a cylindrical anode 804 (which may be connected to an anode terminal 808 for providing a voltage) and a cylindrical cathode sieve 802 (which may be connected to a cathode terminal 806 for providing a voltage), one of which is placed inside the other with a space. Furthermore, insulate and support 818 may

be provided. FIG. 5B illustrates the liquid flow through one of the screen filter devices of the invention in cross-flow filtration mode. In this assembly, the cathode sieve 802 may be placed inside the anode grid 804. As shown in FIG. 5B, liquid containing various particles may be provided via an influent 810 and may flow through the screen filter device to form two streams: the useful effluent (812, 813A, 813B) passing through the cathode sieve 802 and the reject (in other words: concentrate reject 814, 815) containing the larger particles than the sieve size.

[0080] It will be understood that FIG. 5A shows a partially opened device in order to be able to see the internals of the device. Furthermore, it will be understood that FIG. 5B illustrates a cross-section of an internal portion of the device shown in FIG. 5A, so that for example the effluent 813A, 813B shown in FIG. 5B may internally be connected to the effluent 812 shown in FIG. 5A, that the influent 811 shown in FIG. 5B may internally be connected to the influent 810 shown in FIG. 5A, and that the concentrate reject 815 shown in FIG. 5B may internally be connected to the reject 814 shown in FIG. 5A.

[0081] According to various embodiments, the anode may be lined onto the inside filter wall, as shown in FIG. 6A and FIG. 6B, and others portions of the device may be kept the same as in FIG. 5A and FIG. 5B.

[0082] FIG. 6A shows a schematic illustration 900 of a multi-functional screen filter device according to various embodiments, having an inner cathode sieve 802 and outer anode lined on filter support (in other words: an anode liner 902). FIG. 6B shows an illustration 904 of a liquid flow in a cross-flow filtration mode according to various embodiments. Anode support 906 may be provided. Various portions of the device shown in FIG. 6A and FIG. 6B are similar or identical to the device shown in FIG. 5A and FIG.

5B, so that the same reference signs may be used and duplicate description may be omitted.

[0083] FIG. 7A shows a schematic illustration 1000 of a multi-functional screen filter device having an inner anode grid 1002 (in other words: anode mesh) and outer cathode sieve 802 according to various embodiments. FIG. 7B shows an illustration 1001 of a liquid flow in a cross-flow filtration mode according to various embodiments. Various portions of the device shown in FIG. 7A and FIG. 7B are similar or identical to the device shown in FIG. 5A and FIG. 5B, so that the same reference signs may be used and duplicate description may be omitted.

[0084] According to various embodiments, a multi-functional screen filter device may be provided with an anode-cathode assembly such that the anode grid 1002 is placed inside the cathode sieve 802, as shown in FIG. 7A and FIG. 7B. By using this filter device, liquid containing various particles flows through the screen filter device to form two streams, the effluent 814, 1008, 1010, passing through the cathode sieve and the (concentrate) reject 812, 1012, 1014 containing the larger particles than the sieve size.

[0085] It will be understood that FIG. 7A shows a partially opened device in order to be able to see the internals of the device. Furthermore, it will be understood that FIG. 7B illustrates a cross-section of an internal portion of the device shown in FIG. 7A, so that for example the effluent 1008, 1010 shown in FIG. 7B may internally be connected to the effluent 812 shown in FIG. 7A, that the influent 1004, 1006 shown in FIG. 7B may internally be connected to the influent 810 shown in FIG. 7A, and that the concentrate reject 1012, 1014 shown in FIG. 7B may internally be connected to the reject 814 shown in FIG. 7A.

[0086] According to various embodiments, the cylindrical anode grid 1002 in FIG. 7A and FIG. 7B may be replaced by a solid anode bar (in other words: anode rod), as shown in FIG. 8A and FIG. 8B. The other element may be kept the same as in FIG. 7A and FIG. 7B.

[0087] FIG. 8A shows a schematic illustration 1100 of a multi-functional screen filter device having an inner anode rod/bar 1102 and an outer cathode sieve 802 according to various embodiments. FIG. 8B shows an illustration 1104 of a liquid flow in a cross-flow filtration mode according to various embodiments. Various portions of the device shown in FIG. 8A and FIG. 8B are similar or identical to the device shown in FIG. 5A, FIG. 5B, FIG. 7A, and FIG. 7B, so that the same reference signs may be used and duplicate description may be omitted.

[0088] It will be understood that FIG. 8A shows a partially opened device in order to be able to see the internals of the device. Furthermore, it will be understood that FIG. 8B illustrates a cross-section of an internal portion of the device shown in FIG. 8A, so that for example the effluent 1106, 1108, 1110, 1012 shown in FIG. 8B may internally be connected to the effluent 812 shown in FIG. 8A, that the influent 1004, 1006 shown in FIG. 8B may internally be connected to the influent 810 shown in FIG. 8A, and that the concentrate reject 1012, 1014 shown in FIG. 8B may internally be connected to the reject 814 shown in FIG. 8A.

[0089] According to various embodiments, a multi-functional screen filter device may be provided, including of a catalytic metallic sieve cathode and a catalytic anode for ballast water treatment.

[0090] According to various embodiments, the ballast water treatment device may integrate sieving/filtration and electrochemical treatment, and therefore is compact.

[0091] According to various embodiments, the compact ballast water treatment device may perform multiple functions, including particle/liquid separation, oxidant production, filter self-cleaning, as well as electro-floatation.

[0092] According to various embodiments, one of the electrodes in the filter may be a single layer conductive sieve having designed pore shape and size, and therefore low pressure is required and high flux is viable.

[0093] According to various embodiments, the sieve filter may be used to filter out the finer particles/microorganisms and therefore reduce the loading for the following electrochemical treatment.

[0094] According to various embodiments, the anode may be made of materials having high oxygen evolution potential and therefore generate oxidants with high efficiency.

[0095] According to various embodiments, the cathode sieve may be made of materials have hydrogen catalytic properties beneficial to release of hydrogen bubbles to realize anti-clogging and anti-fouling functions, i.e., self-cleaning, therefore cutting off down time due to the backwashing.

[0096] According to various embodiments, the cathode sieve may be coated with conductive materials to enhance its surface properties, such as erosion resistance, corrosion resistance, as well as anti-sticking, to extend filter service life without replacement or maintenance.

[0097] According to various embodiments, if the device is used for other wastewater treatments, such as produced water in oil & gas industry, electro-floatation may be simultaneously realized due to both anode and cathode being able to generate fine gas bubbles.

[0098] According to various embodiments, an electrochemical sieving device may be provided, including an anode component and a cathode component.

[0099] According to various embodiments, the anode may be made of conductive and catalytic materials having high oxygen evolution potential and therefore generates oxidants on the anode surface with high efficiency.

[00100] According to various embodiments, the cathode may be a sieve or screen such that it allows liquid to pass through and selectively reject particles.

[00101] According to various embodiments, the cathode may be made of conductive and catalytic materials having low hydrogen evolution potential and therefore may generate hydrogen bubbles on cathode surface for self-cleaning and/or floatation.

[00102] According to various embodiments, the cathode sieve may be coated with conductive materials to enhance its surface properties, such as erosion resistance, corrosion resistance, as well anti-sticking, to extend filter service life without replacement or maintenance.

[00103] According to various embodiments, both anode and cathode components may be in cylindrical form and one of them (i.e. inner electrode) may be smaller than the other (i.e. outer electrode), such that the two electrodes are arranged in parallel.

[00104] According to various embodiments, the influent may be fed from the cathode sieve such that the anode is in effluent/filtrate.

[00105] According to various embodiments, once a voltage is applied over the two electrodes, the influent may contain more hydrogen gas bubbles and the effluent contains oxidant, via electrochemical reactions on the electrode surfaces.

[00106] According to various embodiments, the compact device may perform multi-functions, including particle/liquid separation, oxidant production, filter self-cleaning, as well as electro-floatation.

[00107] According to various embodiments, the potential industrial applications may include, for example, ballast water treatment in sea tanks, treatment of produced water in oil and gas industry, industrial wastewater treatment, swimming pool water treatment, and treatment of wastewaters containing solid particles and microorganisms.

[00108] While the invention has been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the appended claims. The scope of the invention is thus indicated by the appended claims and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced.

Claims

What is claimed is:

1. A filter device comprising:
an anode; and
a cathode provided at least substantially in parallel to the anode;
wherein the cathode is a sieve configured to provide mechanical filtering; and
wherein a pore size of the cathode sieve is between 0.1 to 100 μm , depending on
the requirement for the quality of a filtrate.
2. The filter device of claim 1,
wherein the cathode comprises a cathode sieve.
3. The filter device of claim 1 or 2,
wherein the anode has at least substantially a shape of a cylinder.
4. The filter device of any one of claims 1 to 3,
wherein the anode comprises an anode grid.
5. The filter device of any one of claims 1 to 4,
wherein the cathode has at least substantially a shape of a cylinder; and
wherein the anode has at least substantially a shape of a cylinder.

6. The filter device of claim 5,
wherein a diameter of the cylinder of the cathode is larger than a diameter of the cylinder of the anode; and
wherein the anode is provided at least substantially in the cylinder of the cathode.
7. The filter device of claim 5 or 6,
wherein a diameter of the cylinder of the cathode is smaller than a diameter of the cylinder of the anode; and
wherein the cathode is provided at least substantially in the cylinder of the anode.
8. The filter device of any one of claims 1 to 7, further comprising:
an insulating layer between the anode and the cathode.
9. The filter device of claim 8,
wherein the insulating layer comprises an insulating spacer grid layer.
10. The filter device of any one of claims 1 to 9, further comprising:
a housing comprising an inside wall;
wherein the cathode is provided inside the housing; and
wherein the anode is lined onto the inside wall.
11. The filter device of any one of claims 1 to 10,

wherein the anode has at least substantially a shape of a rod.

12. The filter device of any one of claims 1 to 11,
wherein the filter device is at least substantially rotationally symmetric with respect to a symmetry axis of a cylinder of the cathode.
13. The filter device of any one of claims 1 to 12, further comprising:
an inlet connected to an internal area of a cylinder of the cathode; and
an outlet connected to an external area of the cylinder of the cathode.
14. The filter device of any one of claims 1 to 13, further comprising:
an inlet connected to an external area of the cylinder of the cathode; and
an outlet connected to an internal area of the cylinder of the cathode.
15. A filtering method comprising:
providing a fluid flow through a filter device comprising an anode and a cathode provided at least substantially in parallel to the anode;
wherein the cathode is a sieve and provides mechanical filtering; and
wherein a pore size of the cathode sieve is between 0.1 to 100 μm , depending on the requirement for the quality of a filtrate.
16. The filtering method of claim 15,
wherein the cathode comprises a cathode sieve.

17. The filtering method of claim 15 or 16,
wherein the anode has at least substantially a shape of a cylinder.
18. The filtering method of any one of claims 15 to 17,
wherein the anode comprises an anode grid.
19. The filtering method of claim 17 or 18,
wherein the cathode has at least substantially a shape of a cylinder; and
wherein the anode has at least substantially a shape of a cylinder.
20. The filtering method of claim 19,
wherein a diameter of the cylinder of the cathode is larger than a diameter of the
cylinder of the anode; and
wherein the anode is provided at least substantially in the cylinder of the cathode.