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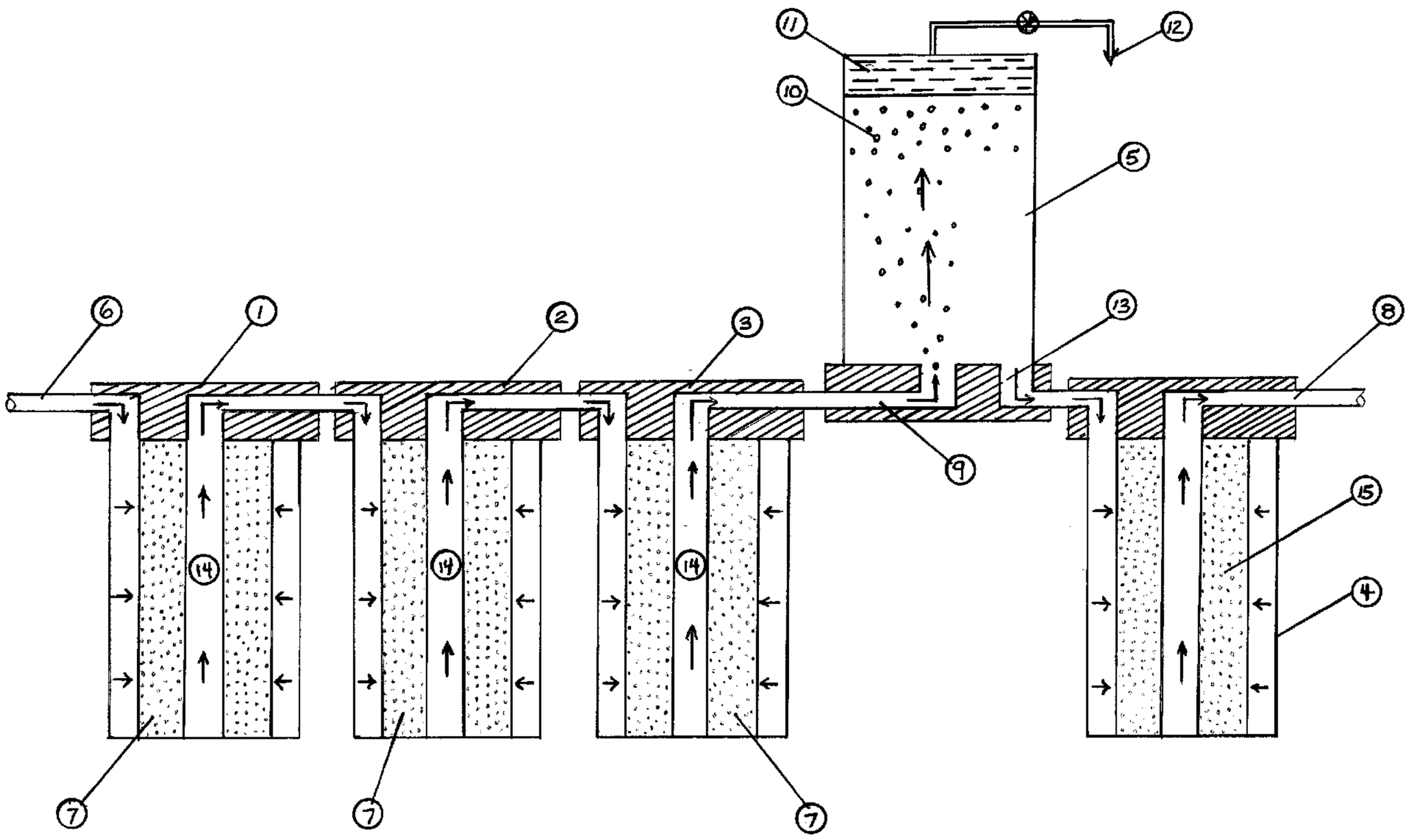
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(54) Titre : PROCEDE ET APPAREIL DE SEPARATION DE LIQUIDES NON MISCIBLES CONTENUS DANS DES FLUIDES AQUEUX

(54) Title: PROCESS AND APPARATUS FOR SEPARATING IMMISCIBLE LIQUIDS FROM AQUEOUS FLUIDS



(57) Abrégé/Abstract:
This invention provides a process and apparatus for separating immiscible liquids such as oil and hydrocarbon based liquids from an aqueous fluid by passing the fluid through a fluid pervious coalescing media designed to coalesce oil particles contained in the fluid into larger oil droplets, a gravity separation stage where the coalesced oil droplets can separate by gravity, and an adsorption/absorption stage where remaining oil dispersions are removed by an oleophilic media capable of attracting and retaining oil particles on its substrate. The process and apparatus significantly increases the longevity of conventional adsorbent/absorbent filters which have to be replaced when they become saturated with oil, and also allows the oil to be recovered for re-use or re-cycling.

ABSTRACT

This invention provides a process and apparatus for separating immiscible liquids such as oil and hydrocarbon based liquids from an aqueous fluid by passing the fluid through a fluid pervious coalescing media designed to coalesce oil particles contained in the fluid into larger oil droplets, a gravity separation stage where the coalesced oil droplets can separate by gravity, and an adsorption/absorption stage where remaining oil dispersions are removed by an oleophilic media capable of attracting and retaining oil particles on its substrate. The process and apparatus significantly increases the longevity of conventional adsorbent/absorbent filters which have to be replaced when they become saturated with oil, and also allows the oil to be recovered for re-use or re-cycling.

Process and Apparatus for Separating Immiscible Liquids from Aqueous Fluids

SPECIFICATION:

FIELD OF THE INVENTION

This invention relates to a process and apparatus for separating immiscible liquids such as oil and hydrocarbon based liquids from an aqueous fluid. Oil and hydrocarbon based liquids as defined herein refer to any liquid which is attracted to an oleophilic surface, and are collectively referred to as oil.

BACKGROUND AND PRIOR ART

Oil is found throughout industry both as naturally occurring and synthetic based products. When these come in contact with aqueous fluids a variety of different types of oily mixtures can be formed. These include free floating oil, oil-in-water emulsions and water-in-oil emulsions. Emulsions can be mechanically or chemically created, with the former being caused by fluid agitation where oil in the fluid is mechanically broken up into very small dispersed particles, and the latter being caused by contact with a surfactant where oil is chemically dispersed as very small oil particles in the fluid. In both cases the oil particles typically won't separate from the aqueous fluid very quickly by gravity due to their small size. It has consequently become necessary to develop alternate oil removal technologies to deal with these smaller oil dispersions.

Many different processes and types of equipment have been developed over the years to do this including density separation, adsorption/absorption systems, chemical removal, coalescing processes and filtration processes.

Density separation generally uses centrifugal force to separate liquids of different densities using equipment such as hydro-cyclones. In these machines centrifugal force is applied to the contaminated fluid causing higher density products to move to the outside of the water column while lower density products move to the inside. This allows a target liquid to be separated from the other fluid and removed. This process is generally restricted in the size of oil particle it can remove to approximately 5-10 microns

or larger. Other processes are usually required to remove smaller particles.

Adsorption and absorption based processes use oleophilic media to attract oil particles from the fluid to a fixed surface as the carrier fluid passes through. One common application of this technology is in the use of disposable oil adsorbing filters. One disadvantage of these systems is that saturation of the media with oil generally requires that it be replaced with new product, and the used media disposed as a waste product. It also doesn't permit recovery of the oil for re-use or re-cycling. In the following discussion 'adsorbent' products generally refer to products which weakly attract oil to the surface of a media while 'absorbent' products generally refer to products which strongly bind or trap oil in the media matrix. For purposes of discussion herein, 'adsorbent' products and 'absorbent' products are collectively to referred to as 'adsorbent' materials.

Chemical treatment processes require addition of chemicals to the fluid, usually requiring substantial residence time for the treated product in a large contact chamber, and often have high operating and maintenance costs.

Coalescing systems use oleophilic media to attract oil particles to its surface where they are encouraged to coalesce and then release from the media as larger droplets downstream.

Filtration systems generally use membranes which are designed to have pore spaces so small that the membrane can strain out large oil particles from the fluid while letting smaller water molecules pass through. Due to the small pore size of membrane required for this process to be effective, this solution is very sensitive to the presence of particulate matter in the fluid stream, and can quickly be plugged up with such matter, requiring frequent cleaning and maintenance.

The fields to which this invention most applies are the adsorbing, coalescing and gravity separation processes noted above. The purpose of the invention is to provide a process and apparatus which allows adsorbent type media to be used much longer before it requires replacement, thereby reducing replacement costs substantially while at the same time allowing oil in the fluid to be recovered for re-use rather than being disposed as a waste product..

Prior patents and patent applications of relevance to the current invention in this area are listed below:

Patent Application #CA 2,582,585; US Patent Application #20080210635, US Pat. #7,264,721, US Pat. #6,475,393; US Pat. #4,493,772; US Pat. #3,937,662; US Pat. #3,878,094; US Pat. #3,738,492 and US Pat. #3,558,482.

METHOD BY WHICH THE PRESENT INVENTION OVERCOMES PRIOR ART PROBLEMS

It is an object of this invention to provide an oil separation process and apparatus which greatly increases the volume of oil that can be processed through a treatment system before the adsorbent media in the system needs to be replaced, thereby reducing treatment costs significantly.

It is a further object of this invention to provide a process and apparatus which permits most of the oil in the aqueous fluid to be recovered for re-use rather than having to be disposed as a waste stream.

It is a further object of this invention to provide a process and apparatus which can treat aqueous fluids containing wide ranges of oil concentrations ranging from 1 mg/l to1,000,000 mg/l.

To accomplish this, three treatment stages are used in the process consisting of a coalescing stage, a gravity separation stage and an adsorption stage. In the first stage, a fluid pervious oleophilic media attracts and coalesces oil particles in the fluid and subsequently releases them downstream as larger oil droplets.

The second stage consists of a gravity separation area where the larger oil droplets discharging from the coalescing stage can float up, or sink depending on their density relative to the carrier fluid, and thereby be separated, removed and recovered from the carrier fluid.

The third stage consists of an oil adsorbing fluid pervious media which attracts and retains remaining oil particles in the fluid onto its substrate, while letting the other fluid pass through as clean product.

Under the above process, media used in the first stage of the treatment operation is designed to become saturated with oil as part of the coalescing and consequently does not require replacement when it

becomes saturated. The second stage of the process consists of a simple open area designed to allow coalesced oil particles to settle out by gravity, and thus has no moving or replaceable parts requiring maintenance. The third stage of the process is the only stage where saturation of media with oil necessitates replacement of the media. Because of the system configuration however, by the time the aqueous fluid reaches this stage most of the oil has been removed by earlier stages, so the length of time required between media replacements is greatly increased.

Disposable oil adsorption filters are widely used in industry to remove trace amounts of oil from aqueous fluids. One apparatus commonly used to accomplish this consists of a product which is commonly referred to as oil 'filters' These aren't actually 'filters' from a technical standpoint as they don't rely on their pore spaces to strain out large oil molecules and let others pass through. Instead they work on the adsorption principle noted earlier whereby the 'filter' contains an oleophilic substrate which has an affinity for oil, causing oil to preferentially attach to the substrate. One feature common to these products is that the media being used to attract the oil typically has a maximum retention capacity for oil which determines how much it can hold before becoming saturated. This capacity is a significant operating consideration in many treatment applications, as it largely determines the feasibility and economics of using the technology for different oil removal applications. For purposes of discussion herein, the term 'oil filter' is used to refer collectively to any oleophilic media which is being used to attract oil.

In testing it was found that the life of these filters can be increased significantly by using a process and apparatus which combines a specific configuration of coalescing filters upstream, adsorbent filters downstream and a gravity stage in between. It has been found in this regard that coalescing and gravity separation processes by themselves cannot normally remove all dispersed oil particles from an aqueous fluid, generally leaving a visible oil sheen on the treated discharge fluid. Conversely, adsorption filters alone can generally remove all oil from an aqueous fluid, but become saturated very quickly if significant concentrations of oil are present, necessitating frequent media replacement. It has been found however, that combining the above processes in a manner which seeks to maximize oil recovery in the second stage results in most of the oil being removed by the system before it can reach the final stage, thereby extending the life of the adsorption filter substantially. Since the downstream adsorption filter is the only consumable item in the system, this will allow users to greatly reduce the operating cost of such a treatment process. The process also allows most of the oil in the fluid to be recovered, providing an

additional environmental advantage over current oil treatment practices.

One of the key aspects to making this process work involves maximizing the size of droplets being released by the coalescing stage. By maximizing the size of these droplets, the downstream gravity stage is more effective for removing the droplets from the fluid. In this regard it was found that this can be accomplished by passing contaminated fluids sequentially through more than one coalescing filter arranged in series prior to reaching the gravity separation stage. Each filter so arranged was found to further increase the size and number of large oil droplets being discharged downstream, thereby allowing them to be recovered easier by the gravity separation stage. Maximizing the amount of oil recovered in this manner is a key to also maximizing the life of the downstream absorption filter, which is the primary aim of the invention.

A practical application of the invention can be illustrated by referring to the current practice of using small disposable fabric type filter cartridges to remove oil from water. One such filter currently used for this purpose consists of a 2.5 in dia. x 10 in long cylindrical filter cartridge which is installed in a hand tightened filter cartridge housing. This arrangement allows a filter cartridge to be quickly and easily replaced by simply unscrewing the filter housing and installing a new cartridge. These filters are typically used in many low flow 'under-the-counter' type applications for the purpose of removing oil from a piped fluid stream. When the filter cartridges become saturated with oil they are replaced with new units and the old ones disposed of as waste products. Regarding oil retention capacity of these filters, US Pat. #7,264,721 describes tests carried out on one such type of filters to ascertain this. Test results presented therein found that two such filters, when processing a fluid containing an oil concentration of 3000 ppm and non-emulsified No.2 oil, were capable of capturing and retaining 85 gms and 185 gms of oil per filter respectively before oil concentrations in the discharge exceeded 5 ppm. US Pat. # 6,475,393 also lists test results for another filter where the oil retention capacity was found to be approximately 165 gms prior to an oil sheen being detectable in the discharge. In typical industrial applications, these results (85 - 185 gms/filter and 165 gms/filter) would generally represent the approximate point at which the filter would need to be replaced in order to maintain a suitable water discharge quality. Treatment of a fluid stream containing high oil concentrations with such units would require replacement efforts and costs proportionate to their retention abilities.

Under the process described in this invention, these results can be improved upon significantly before a filter cartridge would need to be replaced. Tests carried out to demonstrate this used similar 2.5 in dia. x 10 in oil filters made of spun wound polypropylene, with test parameters as described below:

Test Set-Up - Preliminary tests indicated that installing multiple coalescing filters in series significantly increased the volume and number of larger oil droplets that could be generated in the discharge effluent and subsequently removed in the gravity separation stage. The preferred number of filters to use in this regard depended on the type of fluid being processed, with additional coalescing filters generating more such oil particles. From a practical standpoint, a point will be reached in most applications where adding further filters isn't warranted by the extra improvement that such additions provide, and the number to use becomes a field decision based on various considerations such as effluent quality required, space restrictions at the site, etc. In general however, it was found that arranging the coalescing stage in a manner which could reduce emulsified oil content going to the adsorbent filter of 50 ppm or less had the desired effect of increasing filter longevity to a point where replacement costs would no longer be a significant problem in most applications. The number of coalescing filters needed to achieve this can be determined on a site by processing a trial sample of contaminated fluid through a series of small portable filters. The emulsified oil content of fluid passing each filter can quickly define the level of oil reduction being achieved, and consequently the optimum number of coalescing filters needed to fit a specific application from a life cycle cost standpoint.

For purposes of the performance test described below, three 2.5 in dia. x 10 in long spun wound polypropylene filter cartridges were used which had been pre-treated with an oleophilic compound to make them act as coalescing filters. These cartridges were installed in series to represent a three filter coalescing stage in the system. Immediately downstream of the coalescing filters was installed a 5 in dia. empty inverted filter housing to represent the gravity separation stage of the process where coalesced oil droplets discharging from the first stage could separate and float to the surface by gravity. Downstream of the gravity separation chamber a single 2.5 in dia. x 10 in long oil adsorbent spun wound polypropylene filter cartridge was installed which had been pre-treated with an oleophilic compound to make it adsorb oil, representing the third and final stage of the oil removal process. This test arrangement is depicted in Fig. #1.

Test Methodology - The filters and gravity separator noted above were connected together by piping

which allowed test fluids to be injected through an inlet pipe into the first coalescing filter of stage one, following which it flowed through coalescing filter #2, then coalescing filter #3, then the gravity separation chamber, then the oil adsorbing filter #4 and finally to discharge. Test fluids consisted of diesel fuel (sp. gravity = 0.84) and fresh water which were mechanically mixed in a 17 litre container to form mechanical emulsions. This fluid was pumped through the test set up using a centrifugal submersible pump installed in the raw fluid container. The test mixture contained an average oil concentration of 1421 ppm. When the injection pump was engaged, test fluid flowed through the test set-up until the raw fluid container was empty, following which it was refilled with similar fluid and the test resumed. This arrangement was used to simulate actual field conditions expected to be encountered if treating contaminated water on a boat or in an industrial operation where oil in the water would likely be pre-emulsified by an Owner's submersible pump before reaching the treatment system. To ensure that longevity results for filter #4 were not affected by any oil retention capacity offered by the three coalescing filters, the coalescing filters were first pre-conditioned with oil and water before the filter #4 longevity test began. This involved pumping oily water through the first three coalescing filters and the gravity chamber until all three filters were saturated with oil. Such saturation was deemed to have occurred when coalesced oil droplets began discharging from the third coalescing filter and rising in the gravity separation chamber. Filter #4 was only added to the system after this saturation process was complete. The longevity test for filter #4 then commenced to identify how much oil could be injected into the system before filter #4 would become saturated with oil and need to be replaced. This was defined as the point at which a detectable oil sheen could be seen discharging from filter #4. Results of the test were as follows:

- **Test #1** - To provide a reference point for assessing longevity results of filter #4 when used in this system, it was first necessary to identify what the oil retention capacity of filter #4 would have been if it was installed in a conventional set-up and required to process this type of fluid. To do this, three filter cartridges were taken from the same batch of filter material as filter #4, and were then tested to determine their oil retention capacity in a conventional oil filter set-up (i.e.- without the coalescing or gravity separation stage used herein). Results of these tests indicated that filter #4 had an average oil retention capacity of 96.2 gms of oil per filter in the absence of using the new process described herein;
- **Test #2** - The test was then done using the new set-up described herein, consisting of three

saturated coalescing filters arranged in series, a gravity separation chamber and adsorption filter #4. Test results confirmed that 1517 gms of oil could be pumped through the system before a detectable oil sheen began discharging through filter #4, representing an improvement of approximately 1400% in filter longevity by using the process.

As part of this test, it was also noted that coalesced oil droplets rose quickly in the gravity separation chamber as planned, and joined together at the top of the chamber to form a layer of free oil which could be easily removed by opening a discharge port at the top of the container

Based on the above results, the length of time the system could operate before filter #4 would have to be replaced was increased by a factor of more than 14 times, which would translate into substantial cost savings for users. It was noted during the test as well that while the oil droplets were being coalesced as intended during the coalescing stage, the system would have generated even better longevity results if the gravity separation chamber had been larger. Because of the small size of the chamber used in the test set-up, it was found that some of the larger coalesced oil droplets were still being drawn down into filter #4 rather than floating up due to fluid turbulence in the chamber. A larger gravity chamber, or one configured to reduce this turbulence, would eliminate this effect, resulting in a further increase in the downstream the longevity of filter #4.

The bulk of the oil injected into the system was recovered as free oil at the top of the gravity chamber, allowing it to be re-used or re-cycled.

Thus it may be seen that the process described allows a significant improvement in oil removal performance over conventional adsorption type processes, and a proportionate decrease in the cost of replacing filters in such applications. It also allows a significant reduction in the amount of waste material generated from such systems by allowing the oil to be recovered for re-use.

The above example is provided only for the purpose of illustrating how the process and apparatus works. For those skilled in the art it will be evident from the preceding description that the process can be applied to any type of oil treatment application which uses an adsorption/absorption stage. As such, many equipment arrangements can be deduced to take advantage of the improved performance offered ranging from small filter systems described above, to large systems such as those typically used in the oil

production industry.

The invention differs from the process described in US Pat. #3,558,482 in that it works for pollutants heavier than water as well as lighter than water, it works for 'oil-in-water emulsions' as well as 'water-in-oil emulsions', it provides an improved and definable means of optimizing results through proper design and configuration of the coalescing stage and it doesn't require the use of a back-washable granular filter bed.

LIST OF FIGURES AND DESCRIPTION OF THE INVENTION

In drawings which illustrate embodiments of the invention, Figure 1 is a cross-sectional view through the invention as it would apply to one preferred embodiment.

The invention as illustrated consists of an initial coalescing stage comprising three coalescing oil filters installed in series (1), (2), (3), a gravity separation chamber (5), and an adsorption/absorption chamber (4) containing a single oil adsorbing/absorbing filter (15). Contaminated inlet fluid enters the first coalescing chamber (1) through a pipe or other means of conveyance (6). In the coalescing chamber (1) the fluid passes through a fluid pervious oleophilic coalescing media (7) which causes oil dispersions in the fluid to attach to the surface of the media and coalesce into larger oil particles. These particles grow in size until they release from the media (7) and re-enter the fluid flow (14) as larger oil droplets. The coalesced oil droplets and carrier fluid from filter #1(14) then pass through the second coalescing chamber (2) in a similar manner and finally through third coalescing chamber (3), each time increasing the size of oil droplets for removal by the next stage of the process. The coalesced oil droplets and carrier fluid then enter a gravity separation area (5) through a pipe or other means of conveyance (9) where the coalesced oil droplets (10) separate from the carrier fluid and float to the top of the container. The oil droplets which float to the top of the chamber (5) coalesce there to form a free oil layer at the top (11) which can be removed through a discharge outlet (12) provided for that purpose. The remaining aqueous fluid (13), with most of the oil now gone, then flows to a final adsorption/absorption chamber (4) where remaining oil in the fluid is captured and removed by a fluid pervious oleophilic media (15) which is capable of attracting oil from the carrier fluid and affixing it to its media surface or substrate. The carrier fluid, now free of oil, discharges from the system as clean fluid through a pipe (8) or other means of conveyance.

In the above illustration, the treatment chambers consisted of individual circular filter housings which were pre-formed to allow the bottom part of the housing to be screwed to a top manifold for ease of installing filter cartridges. The oleophilic media used in the system consisted of pre-treated spun wound circular filter cartridges which fit inside the filter housings. Those skilled in the art will recognize that there are many different types, sizes and shapes of process chambers and media other than illustrated in fig. 1 which can be used with this process without departing from the intent of the invention, such as use of larger or multiple media chambers in the coalescing stage to increase the amount of oil which can be removed in the next stage; using more than one gravity separation chamber to increase the size range of oil droplets which can be removed using the process; using larger or multiple adsorption/absorption media units in the final stage to increase media longevity or facilitate media replacement without having to shut down the system, etc. All such modifications are included in the process described herein as long as the concept of a coalescing stage, gravity separation stage and adsorption/absorption stage is utilized.

In another embodiment of the invention, the coalescing stage may consist of any shape or size of container which promotes the movement of aqueous fluid from one side of the fluid pervious coalescing media to the opposite side, including pressurized and non-pressurized vessels.

In another embodiment of the invention the coalescing media (7) may be any shape, size, type or configuration as long as it is effective for coalescing dispersed oil into larger droplets as the fluid passes through the media. Such media may be naturally occurring or pre-treated to provide it with enhanced oil attraction abilities.

In another embodiment of the invention the coalescing media (7) may be used in single or multiple units, and placed in one container or a plurality of containers.

In a preferred embodiment of the invention, the gravity separation stage (5) would be designed in accordance with Stoke's Law to maximize the amount of oil that can be removed in a given time period. Stoke's Law can be used to determine how big the gravity separation chamber would need to be to facilitate floating or sinking of particles based on their size and relative density in a given time frame. A larger container offering a longer residence time, or a container geometry which minimizes fluid velocity opposite in direction to the direction the oil particle is floating or sinking, will allow smaller size oil

droplets to separate from the carrier fluid and maximize the amount of oil which can be removed in the gravity separation stage (5). The size and shape of container to be used for this stage will thus depend on specific project applications such as space restrictions and cost considerations. This includes configurations where the gravity separation area is attached to or located within the same container as the coalescing media, or multiple gravity separation stages such as a separate ones for each coalescing chamber.

In another embodiment of the invention, the adsorption/absorption stage (4) may comprise any shape or size of container which promotes the movement of fluid from one side of the fluid pervious media to the opposite side, including pressurized and non-pressurized containers.

In another embodiment of the invention the adsorption/absorption media (15) may be any shape, size or configuration that is effective in capturing dispersed oil from the fluid and removing it from the fluid flow as fluid passes through the media.

In another embodiment of the invention the adsorption/absorption media (15) may be installed in individual or multiple units and in one container or a plurality of containers..

In another embodiment of the invention, the adsorption/absorption media (15) may be a naturally occurring oleophilic material, or a material that has been pre-treated to make it oleophilic or more oleophilic, as long as the final material is effective in capturing oil and removing oil from the fluid stream as fluid passes through the media.

In another embodiment of the invention, a re-circulation feature may be added to any stage of the process to allow treated or partially treated fluid from one stage to be returned to a previous stage for additional treatment to increase longevity of the adsorption/absorption media (15).

In another embodiment of the invention, the system may be equipped with pressure guages, oil sensors, discharge valves, solenoid valves, motorized valves, back-washing mechanisms and the like for the purpose of automating operation of the system, allowing it to be cleaned remotely, or allowing oil to be collected or discharged from the system automatically.

ONE INTENDED USE OF THE INVENTION

One preferred use of the invention is for use in treating oily water generated by small oily water generating operations such as machine shops, car washes and boats where improved filter longevity would reduce operating costs significantly.

CLAIMS:

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1) A process and method of separating immiscible liquids in aqueous solutions where one of the liquids is an oil or hydrocarbon based product having a different density than the other liquid(s) comprising:

(a) Feeding the aqueous solution first through a fluid pervious coalescing stage which coalesces the dispersed oil particles and releases them as larger oil droplets downstream;

(b) Providing a gravity separation area downstream of the coalescing stage where the larger oil droplets can separate from the carrier fluid by gravity;

(c) Feeding the remaining aqueous fluid from the gravity stage through an adsorption/absorption stage in which a fluid pervious oleophilic media with an affinity for oil removes the remaining oil from the fluid while allowing the other liquid(s) to pass through.

2) A process as defined in Claim 1 in which the coalescing stage consists of more than one coalescing filter arranged in series such that each filter sequentially increases the size of the oil droplets being released to the gravity separation stage, thereby making it possible for the gravity separation stage to remove a higher percentage of oil from the fluid;

3) A process as defined in Claims 1 to 2 in which the coalescing stage preferably contains three or more coalescing filters arranged in series;

4) A process as defined in Claims 1 to 3 in which the coalescing and adsorption/absorption stages utilize fluid pervious media in the form of easily removable and replaceable pre-formed filter cartridges.

5) A process as defined in Claims 1 to 4 in which the coalescing stage and/or the adsorption/absorption stage utilizes fluid pervious media which has been pre-treated to make it more attractive to oil and hydrocarbon based products;

6) A process as defined in Claims 1 to 5 in which the gravity separation stage can consist of more than one separation area such as separate areas located downstream of each coalescing element;.

7) A process as defined in Claims 1 to 6 in which any or all stages of the process may be pressurized or non-pressurized, and housed in open or closed containers.

8) A process as defined in Claims 1 to 7 in which the direction of fluid flow through any stage of the system can be reversed periodically to backwash or clean the system or to re-circulate fluids through the same elements for additional treatment;

9) An apparatus for separating immiscible liquids in aqueous solutions where one of the liquids is an oil or hydrocarbon based product having a different density than the other liquid, comprising:

(a) A coalescing chamber with a means of entry to allow fluids in, a means of exit to allow fluids out, and a space in the chamber for accommodating a fluid pervious oleophilic media capable of coalescing oil particles and releasing them as larger droplets to the downstream side of the media;

(b) A gravity separation area located downstream of the coalescing chamber with a means of entry to allow fluids in from the coalescing chamber, a means of exit to allow coalesced fluids out, a means of exit to allow non-coalesced fluids out and a space in the chamber for allowing coalesced oil droplets to separate and collect by gravity;

(c) An adsorption/absorption area located downstream of the gravity separation area with a means of entry to allow fluids in from the gravity separation area, a means of exit to allow fluids out, and a space in the chamber for accommodating a fluid pervious oleophilic media capable of capturing dispersed oil particles and removing them from the fluid stream as it passes through..

10) An apparatus as defined in Claim 9 in which any or all of the treatment chambers may be pressurized or non-pressurized;

11) An apparatus as defined in Claims 9 to 10 in which fluid can be fed into any or all of the treatment chambers by either gravity flow or by pressurized flow;.

12) An apparatus as defined in Claims 9 to11 in which the coalescing media can be either a naturally occurring fluid pervious oleophilic material having an affinity for oil, or a material which has been pre-treated to provide it with such an affinity, or an improved affinity, for oil;.

13) An apparatus as defined in Claims 9 to 12 in which the coalescing stage comprises one or more coalescing elements arranged in series for the purpose of sequentially increasing the size of oil droplets that are released downstream to the gravity separation stage;

14) An apparatus as defined in Claims 9 to 13 in which one or more coalescing elements can be located in the same coalescing chamber or in a plurality of separate chambers arranged in series;

15) An apparatus as defined in Claims 9 to 14 in which the gravity separation area can be either a separate collection area located downstream of the coalescing stage, or a plurality of such areas located downstream of individual coalescing elements;.

16) An apparatus as defined in Claims 9 to 15 in which the gravity separation area can be located in its own container separate from the coalescing chamber(s), or in the same container(s) as the coalescing element(s), as long as a tranquil area exists where oil droplets from the coalescing stage can separate from the carrier fluid and collect;.

17) An apparatus as defined in Claims 9 to 16 in which the adsorption/absorption media consists of a media which is capable of absorbing and removing oil from a fluid stream, or adsorbing and removing oil from a fluid stream, or both;

18) An apparatus as defined in Claims 9 to 17 in which the adsorption/absorption media can be located in one, or more than one, chamber for purposes of facilitating equipment maintenance/replacement activities or otherwise;

19) An apparatus as defined in Claims 9 to 18 in which fluid flow through the system can be either continuous or discontinuous;

20) An apparatus as defined in Claims 9 to 19 in which the coalescing chamber(s), gravity separation area(s) and/or adsorption/absorption chamber(s) can be cylindrical cartridge housings which allow the filters to be installed and removed by hand, making them easy to service.

21) An apparatus as defined in Claims 9 to 20 in which the coalescing media and/or the adsorption/absorption media can consist of cylindrical filter cartridges which fit into removable filter cartridge housings, which either have a natural affinity for oil, or have been treated to provide an affinity, or increased affinity, for oil;

22) An apparatus as defined in Claims 9 to 21 in which the coalescing and adsorption/absorption media elements consist of materials which can be manufactured to specific pore sizes and porosities for use in different applications;.

23) An apparatus as defined in Claims 9 to 22 in which one or more stages of the invention is installed or retro-fitted into existing equipment such as an API gravity oily water separator to make it operate more efficiently, where one of the stages of the process, such as the gravity separation stage, is provided by the existing equipment;

24) An apparatus as defined in Claims 9 to 23 in which the direction of inlet flow through the gravity separation stage is upwards if the oil is less dense than the carrier fluid, and downwards if it

denser than the carrier fluid.

25) An apparatus as defined in Claims 9 to 24 in which the coalescing media preferably consists of a material having pore spaces ranging in size from 1 - 100 micrometers, but more preferably 1 - 10 micrometers and most preferably from 1 - 5 micrometers;

26) An apparatus as defined in Claims 9 to 25 in which two or more coalescing elements may be reduced by installing a lesser number of elements which contain the same media thickness as the combined larger group;

27) An apparatus as defined in Claims 9 to 26 in which other treatment equipment is used upstream of the system to remove products from the fluid which this apparatus is not designed to treat, such as particulate matter;

28) An apparatus as defined in Claims 9 to 27 in which the treatment system is provided with manually or automatically operated valves at high and low points of the system to facilitate removal of separated fluids and flushing of the system.

29) An apparatus as defined in Claims 9 to 28 in which the system can operate with or without moving parts, electrically activated components or exterior energy requirements.

30) An apparatus as defined in Claims 9 to 29 in which automatic controls are installed to allow the system to operate automatically or in unattended mode.

31) An apparatus as defined in Claims 9 to 30 in which a clean water source is connected downstream of filter #4 to permit the water flow direction to be reversed for purposes of cleaning or back flushing.

32) An apparatus as defined in Claims 9 to 31 in which an oil sensor probe is installed in the gravity separation area for the purpose of detecting the presence of oil when it reaches a pre-determined depth or concentration in the chamber;

33) An apparatus as defined in Claims 9 to 32 in which an oil content monitor is connected downstream of the adsorption/absorption stage to monitor oil concentrations in the discharge liquid when operating, and to send signals to automatic controls which can cause automatic re-circulation of discharge fluid back to the source if discharge concentrations exceed desired levels;

34) An apparatus as defined in Claims 9 to 33 in which the coalescing chamber, gravity separation chamber and adsorption/absorption chamber can be manufactured of any materials suitable for holding oil and aqueous fluids at the pressures to be used and for the specific application involved.

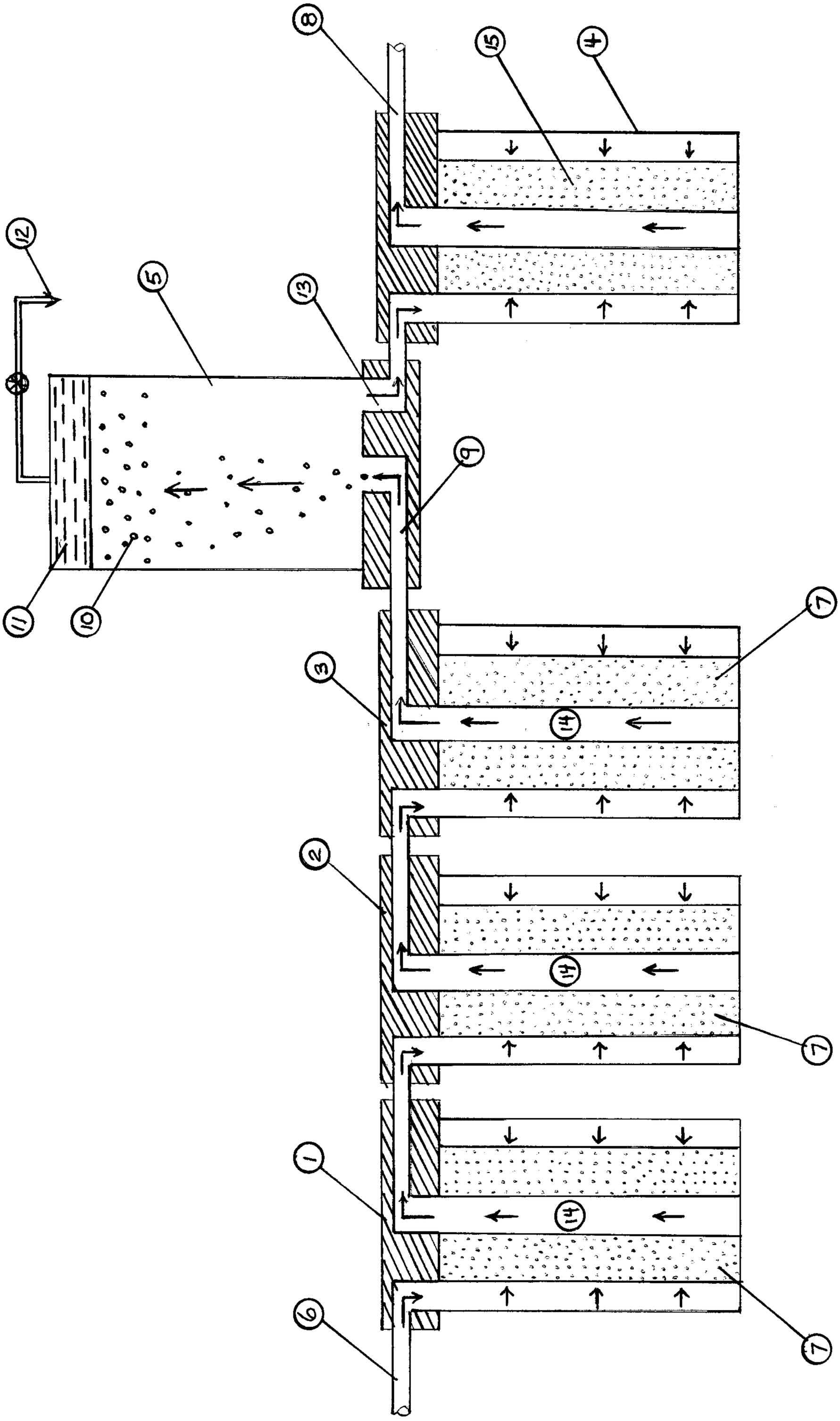
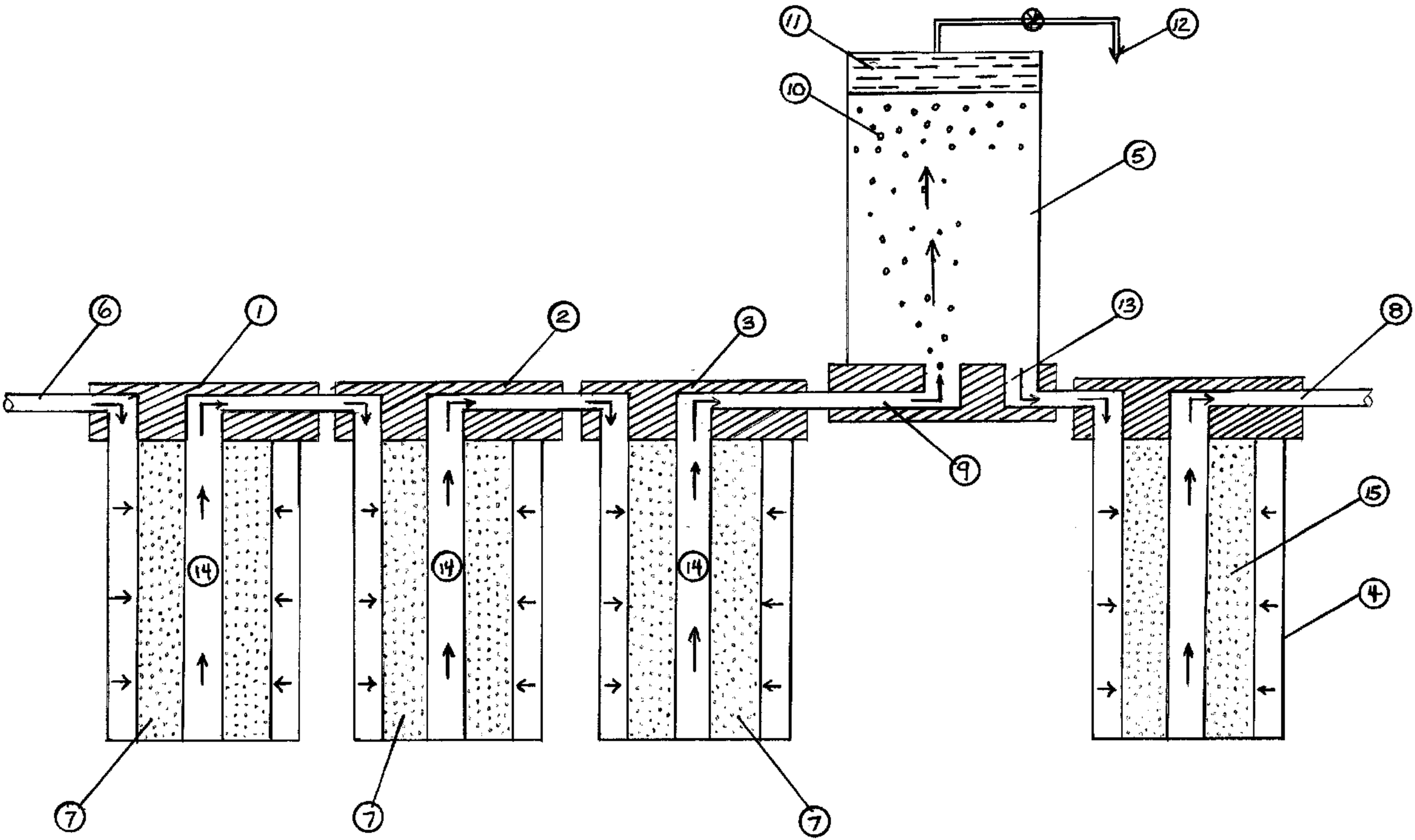


FIGURE 1


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