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- (71) Applicant (for all designated States except US): NEPSUS  
TECHNOLOGIES PTY LTD [AU/AU]; 12 Weir Street,  
Glen Iris, Victoria 3146 (AU).
- (72) Inventor; and
- (75) Inventor/Applicant (for US only): LUXENBERG, Sam  
[US/US]; 13 Windflower, Coto De Caza, California 92679  
(US).
- (74) Agent: PHILLIPS ORMONDE FITZPATRICK; Level  
21, 22 & 23, 367 Collins Street, Melbourne, Victoria 3000  
(AU).

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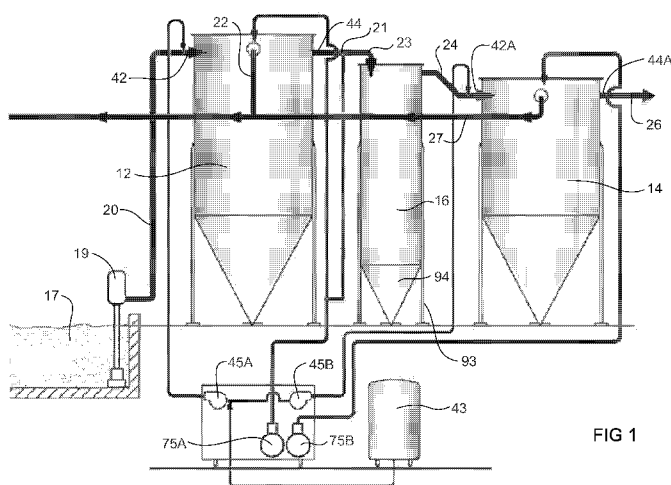


FIG 1

(57) Abstract: An improved automated method of controlling the filtering characteristics of a continuous up-flow granular media filter (12, 14). The filter (12, 14) is designed to treat an influent liquid (20, 24) which includes impurities to produce a treated liquid effluent (21, 26). The granular media filter (12, 14) includes a media filter bed (70) and an airlift pump (76) that moves granular media from a removal (point 38) in the media filter bed (70) to a deposit point (36) in the media filter bed (70). The method includes the steps of: monitoring the impurities level of the influent (20, 24); converting the influent (20, 24) impurities level into an impurities signal input to a computer (118), which uses computer software to interpret the impurities signal input; and using the impurities signal to control the air inflow rate to the airlift pump (76) to maintain the target ratio range between the size of captured solids in the filter (12, 14) and the size of the media filter bed (70) of the granular media filter (12, 14).



## INFLUENT TREATMENT PROCESS

### Field of the Invention

[0001] The present invention generally relates to an influent treatment process. The invention is particularly applicable for removal of impurities and pollutants from water and wastewater and it will be convenient to hereinafter disclose the invention in relation to that exemplary application. However, it is to be appreciated that the invention is not limited to that application and could be used for any liquid influent treatment operation.

### Background of the Invention

[0002] The following discussion of the background to the invention is intended to facilitate an understanding of the invention. However, it should be appreciated that the discussion is not an acknowledgement or admission that any of the material referred to was published, known or part of the common general knowledge as at the priority date of the application.

[0003] Granular media filters, such as sand filters, can be used as part of a water treatment process to purify water or wastewater. A coagulant, such as polyaluminium chloride, can be mixed with influent waste to enhance the filtering characteristics of the sand filter bed. The coagulant forms a filtration gel layer within the sand media that acts as a chemical and physical filter barrier which separates contaminants from the water. As the water moves up through the filter bed, suspended solids are trapped in the coagulant gel that is held in place by the filter bed.

[0004] The sand in these types of sand filters must be cleaned to remove the solid impurities captured in the sand filter media. In some sand filters, the sand filtrate is continuously cleaned while the filter is in operation. In these filters, dirty sand is removed from the filter bed, washed and returned to a clean part of the filter bed. This avoids the need to shut down the apparatus to conduct a filtrate cleaning process.

[0005] One example of a sand filter apparatus which includes a continuous cleaning process is disclosed in United States Patent No. 5,454,959. This apparatus uses a moving sand filter bed in which a portion of the filter bed media is continuously removed from a recessed chamber below the floor of the filter bed using an airlift pump. This sand is transported by gas airlift through a lift conduit to a wash box located above the filter bed, and cleaned by a countercurrent flow of the filtrate. The clean sand is recycled back to a location at or near the top of the sand filter bed.

[0006] The continuous filtration process can be controlled by computer or programmable logic controller. In United States Patent No 7,381,336, a continuous backwash upflow media (CBUM) process is taught which uses a head pressure gauge located at the influent inlet of a granular media filter to continually monitor the head pressure at the influent inlet. Movement of the sand filter bed is automatically increased or decreased relative to the size of the captured solids inventory by controlling the amount of air introduced into the airlift based on computer signal input from the head pressure gauge.

[0007] Further refinement of the control and/or filtering process is desirable. It would therefore be desirable to provide an improved or alternative method and apparatus for the treatment of influent that produces a filtered effluent of a desired purity level.

### **Summary of the Invention**

[0008] A first aspect of the present invention relates to an improved automated method of controlling the filtering characteristics of a continuous upflow granular media filter. The filter is designed to treat an influent liquid which includes impurities to produce a treated liquid effluent. The granular media filter includes a media filter bed and an airlift pump that moves granular media from a removal point in the media filter bed to a deposit point in the media filter bed. The method includes the steps of:

monitoring the impurities level of the influent;

converting the influent impurities level into an impurities signal input to a computer, which uses computer software to interpret the impurities signal input; and

using the impurities signal to control the air inflow rate to the airlift pump to maintain the target ratio range between the size of captured solids inventory of the granular media filter and the size of the media filter bed of the granular media filter.

[0009] The filtering characteristics of a continuous upflow granular media filter can therefore be controlled by monitoring the impurities level, being mostly a function of the solid contaminant content of the influent, and using this parameter to control operation of the airlift pump. The speed of operation of the airlift pump changes the speed of removal of the dirty filter media, and thus the efficiency of filtration of the media. This in turn affects the level of the chemical and physical filter barrier within the filter media. Control of the contaminant value of the influent can be advantageous during conditions of fluctuating influent quality.

[0010] The impurities level can be measured using any suitable device. In a preferred embodiment, a measurement of the turbidity of the influent is used to determine the impurities level in the influent.

[0011] The rate of air inflow rate to the airlift pump is preferably adjusted to maintain a target ratio range between the size of the captured solids inventory and the size of the granular media bed within the system of between about 10 and about 30 standard cubic feet per hour (SCFH).

[0012] Other process variables can be monitored and controlled in addition to the turbidity of the influent to control the filtering characteristics of a granular media filter. For example, the contaminant value of the effluent (which is a function of the turbidity of the effluent) of the media filter can also be used as a control variable for a granular media filter, and more specifically used as a control parameter for the addition of coagulant(s) to the influent.

[0013] In these embodiments, the method can further include the steps of:

- monitoring the impurities level of the effluent;
- converting the effluent impurities level into a dose signal input to a computer which uses computer software to interpret the dose signal; and
- using the dose signal to control the amount of coagulants added to the influent stream and thereby maintain a target ratio between the size of captured solids inventory of the granular media filter and the size of the media filter bed of the granular media filter.

[0014] The impurities level can be measured using any suitable device. In a preferred embodiment, a measurement of the turbidity of the effluent is used to determine the impurities level in the effluent.

[0015] Again, the rate of air inflow rate to an airlift pump is preferably adjusted to maintain a target ratio range between the size of the captured solids inventory and the size of the granular media bed within the system of between about 10 and about 30 SCFH. In some embodiments, the effluent turbidity value is displayed on a computer screen. The amount of coagulant can then be adjusted by sending a computer signal to a dose rate pump to change the amount of polymer injected into the influent.

[0016] Pressure measurements can also be used as control parameters for a granular media filter. In these embodiments, the method can further include the steps of:

- monitoring an inflow head pressure at a first influent inlet of the first continuous upflow granular media filter;
- converting the head pressure into a pressure signal input to a computer which uses computer software to interpret the pressure signal; and
- using the pressure signal to control the air inflow rate to an airlift pump to maintain the target ratio range between the size of captured solids inventory of the granular media filter and the size of the media filter bed of the granular media filter.

[0017] In each of these methods, optimal operation parameters for the continuous upflow granular media filter can be established during commissioning of the filter by obtaining initial measurements of operation of the filter for different airlift rates, expected inflow, selected inflow and other operational parameters.

[0018] It should also be appreciated that the filtering characteristics of a granular media filter can be controlled using any combinations of the above steps. In some embodiments, control by monitoring the turbidity of the influent may be sufficient. In other embodiments, control may be achieved through the combined monitoring and control of influent turbidity, effluent turbidity and head pressure of the influent.

[0019] A second aspect of the present invention relates to a process for treating a liquid that includes impurities. This process can include a number of process vessels. In a broad form, the process includes:

- a first continuous upflow granular media filter in which the liquid is fed as a first influent and treated to produce a first effluent and a first reject, the first granular media filter including a media filter bed and an airlift pump that moves granular media from a removal point in the media filter bed to a deposit point in the media filter bed;

- an influent impurities meter at an inlet for the influent of the first continuous upflow granular media filter; and

- a control system, preferably a computer control system, operatively linked to the influent impurities meter which controls the operation of the airlift pump in the first continuous upflow granular media filter to maintain a target ratio range between the size of captured solids inventory of the first granular media filter and the size of the media filter bed of the first granular media filter.

[0020] This aspect of the present invention provides a process which removes impurities and pollutants from water and wastewater that includes an automated control system which monitoring and controls process variables in the process. In this broad form, operation of the airlift pump is controlled by the impurities level measurements, preferably turbidity measurements of the influent to the

first granular media filter. As can be appreciated, this relationship can be easily determined during commissioning of the process, through baseline measurements which then allows the operation of the airlift pump to be controlled relative to this baseline data. In some embodiments, the airlift pump is operated by an air compressor and the control system controls operation of the air compressor.

[0021] Further process parameters can be used to further control the filtering characteristics of the liquid treatment process. Most granular media filters have one or more coagulants added to the first influent prior to the first influent being fed into the first continuous upflow granular media filter to form a chemical and physical filter barrier within the granular media within the filter. The coagulation chemical can be any suitable formulation. One suitable coagulation chemical is polyaluminium chloride. In these embodiments, the process can further include:

- an effluent impurities meter at an outlet for the effluent of the first continuous upflow granular media filter; and

- a control system, preferably a computer control system, operatively linked to the effluent impurities meter which controls the operation of coagulation chemical addition to the first continuous upflow granular media filter to maintain a target ratio range between the size of captured solids inventory of the first granular media filter and the size of the media filter bed of the first granular media filter.

[0022] The impurities or contaminants value of the effluent of the first granular media filter is therefore monitored and this information on the influent quality is used to control the amount of coagulants added to the first granular media filter, and thus the characteristics of the chemical and physical filter barrier within the first granular media filter. The level of impurities in the effluent can be measured using any type of impurities meter. Preferably, a turbidity meter is used.

[0023] Again, head pressure monitoring can also be used as a further control parameter. In some embodiments the method can further include the steps of:

a head pressure detector for monitoring an inflow head pressure at the inlet of the influent of the first continuous upflow granular media filter; and

a control system, preferably a computer control system, operatively linked to the head pressure detector which controls the operation of an airlift pump in the first continuous upflow granular media filter to maintain a target ratio range between the size of captured solids inventory of the first granular media filter and the size of the media filter bed of the first granular media filter.

[0024] The head pressure detector can comprise any suitable pressure detector such as a pressure sensor or the like. In a preferred embodiment, the head pressure detector is a liquid level sensor located at the inlet for the first influent of the first continuous upflow granular media filter. The control system preferably responds to changes in backpressure based on baseline data for the process.

[0025] Baseline data for relative measurement of process parameters for each of the above control systems can be experimentally obtained, for example during commissioning. Such experiments can establish the proper baseline coagulant flow rate for relative measurements during operation of the continuous upflow granular media filter. Baseline optimal operation parameters for the continuous upflow granular media filter can include measurements of operation of the filter for different airlift rates, expected inflow, selected inflow and other operational parameters.

[0026] Further process vessels can be used in the process to improve the treatment process of the influent fluid.

[0027] Some embodiments include a bioreactor in which the first effluent is fed as a second influent and treated to substantially remove the nitrogen content thereof to produce a second effluent. The bioreactor preferably comprises a single closed vessel having a low oxygen (anoxic) environment. The second influent is preferably maintained as a low carbon content influent favourable to the Partial Nitritation/Anammox process where ammonium nitrogen – is partially oxidised to nitrite by nitrosomonas spp. The Anammox bacteria uses nitrite as

an electron acceptor without need of organic material and anaerobically converts ammonium and nitrite to nitrogen gas and water. The low oxygen and phosphorus levels do not allow the population of nitrobacter spp. to build up to a level that allows oxidation of nitrite to nitrate.

[0028] The bioreactor can also include a flexible media bed which houses nitrogen removal bacteria. The flexible media may have any suitable form, including sheet, particulate, rods, wire, sponge, woven fabric or the like. In one preferred embodiment, the flexible media bed comprises balls or beads. Similarly, the flexible media bed can be constructed of any suitable material. In a preferred embodiment, the flexible media bed of the bioreactor includes a polyvinyl alcohol gel to house the bacteria. The nitrogen removal bacteria in the flexible bed preferably use ammonium as electron donor and nitrite as electron acceptor to remove nitrogen compounds. Both ammonium oxidizing bacteria (*Nitrosomonas* spp.) and anaerobic ammonium oxidizing (anammox) bacteria can be used in the bioreactor. In a preferred embodiment, the bacteria culture is predominantly anammox as the specific ammonium and nitrite removal rates of anammox bacteria are generally significantly faster than those of *Nitrosomonas* spp1.

[0029] The treatment characteristics of the bioreactor can also be controlled through monitoring and control of process parameters of the bioreactor. For example, some embodiments of the process can include:

- a dissolved oxygen sensor to monitor the dissolved oxygen level in the bioreactor, preferably located generally near the centre of the reactor; and

- a control system operatively linked to the dissolved oxygen sensor, the control system introducing further oxygen, preferably diffused air, into the bioreactor when the dissolved oxygen level drops below a desired set point.

[0030] The controller preferably maintains the dissolved oxygen levels between 0.7 and 1.5 mg/L.

[0031] The bioreactor can also include one or more ammonia sensors operatively linked to the control system of the bioreactor.

[0032] The controller is preferably a computer controller which uses computer software to interpret the level of dissolved oxygen from the dissolved oxygen meter signal. The computer software can be operatively linked to a mass flow controller which controls operation of an air compressor. The controller changes a valve setting of the air compressor to provide air through a tube connected to the influent to the bioreactor. The computer software preferably instructs the controller to reduce or shut off a supply of oxygen from the air compressor once the desired level of oxygen has been reached.

[0033] Further granular media filters can be used in the liquid treatment process. In some embodiments, the process includes a second continuously operated granular media filter in which the second effluent is fed as a third influent and treated to produce a third effluent and a second reject. This second continuously operated granular media filter is preferably used as a polishing filter for the second effluent from the bioreactor.

[0034] The second granular media filter can include a media filter bed and an airlift pump that moves granular media from a removal point in the media filter bed to a deposit point in the media filter bed.

[0035] The second continuously operated granular media filter preferably includes similar automatic control systems as used in the first continuously operated granular media filter. Process parameters that can be measured for these control systems include:

- influent impurity level using an influent impurities meter at an inlet of the influent of the second continuous upflow granular media filter;

- effluent impurity level turbidity using an effluent impurities meter at an outlet of the effluent of the second continuous upflow granular media filter; or

- inflow head pressure (or back pressure) at the inlet of the second continuous upflow granular media filter using a head pressure detector;

[0036] The system can also include a control system, preferably a computer control system, operatively linked to at least one of:

the influent impurities meter which controls the operation of the airlift pump in the second continuous upflow granular media filter to maintain a target ratio range between the size of captured solids inventory of the second granular media filter and the size of the media filter bed of the second granular media filter;

the effluent impurities meter which controls the operation of coagulation chemical addition to the second continuous upflow granular media filter to maintain a target ratio range between the size of captured solids inventory of the second granular media filter and the size of the media filter bed of the second granular media filter; or

the head pressure detector which controls the operation of the airlift pump in the second continuous upflow granular media filter to maintain a target ratio range between the size of captured solids inventory of the second granular media filter and the size of a granular media filter bed of the second granular media filter.

[0037] The level of impurities in the influent and effluent of the second granular media filter can be measured using any type of impurities meter. Preferably, a turbidity meter is used. Similarly, the head pressure detector can comprise any suitable pressure detector such as a pressure sensor or the like. In a preferred embodiment, the head pressure detector is a liquid level sensor located at the inlet for the first influent of the second continuous upflow granular media filter. Each of the first and second continuous upflow granular media filters can use any suitable media as a filter media. In a preferred embodiment, sand is used as a filter medium.

[0038] To enhance treatment, the process can further include at least one solid separation apparatus in which the liquid undergoes a solid separation step to selectively remove suspended solids therefrom prior to being fed into the first continuously operated granular media filter.

[0039] The present invention provides in yet another aspect, a system for treating a liquid having impurities therein, including:

a first continuous upflow granular media filter in which the liquid is fed as a first influent and treated to produce a first effluent and a first reject; and

a bioreactor in which the first effluent is fed as a second influent and treated to substantially remove the nitrogen content thereof to produce a second effluent.

[0040] Some embodiments may also include a second continuously operated granular media filter in which the second effluent is fed as a third influent and treated to produce a third effluent and a second reject.

[0041] This aspect of the present invention provides a process and apparatus for the removal of impurities and pollutants from water and wastewater using a continuously operated granular media filtration process with an integrated bioreactor. The apparatus preferable uses the control systems outlined above for monitoring and controlling each of the process variables independently.

### **Brief Description of the Drawings**

[0042] The present invention will now be described with reference to the figures of the accompanying drawings, which illustrate particular preferred embodiments of the present invention, wherein:

[0043] Figure 1 is a diagram showing a water treatment process according to one preferred embodiment of the present invention.

[0044] Figure 2 is a schematic view a sand filter used in the process shown in Figure 1.

[0045] Figure 3 is a schematic view a bioreactor used in the process shown in Figure 1.

### **Detailed Description**

[0046] Figure 1 shows one preferred water and wastewater treatment process according to the present invention. The illustrated treatment process 10 includes two sand filters 12 and 14 and a bioreactor 16 located between each of

the sand filters 12, 14. The treatment process can be used to remove contaminants from wastewater to produce a filtered, oxidized effluent suitable for reuse for certain purposes.

[0047] In the general process, an influent, in this case wastewater 20, which includes impurities, is pumped from an equalisation basin 17 using an influent pump 19 into the feed inlet 42 of the first sand filter 12. This wastewater 20 is treated in this sand filter 12 to produce a filtered water effluent 21 and a first reject 22 of a substantial amount of the impurities content of the influent wastewater 20. The filtered water effluent 21 is fed as a second influent 23 into the bioreactor 16 and treated to substantially remove the nitrogen content thereof. Treated water 24 exits the bioreactor from outlet 89 (Figure 3), and is fed into the feed inlet 42A of the second sand filter 14. The second sand filter 14 is a polishing filter, used to substantially remove any remaining suspended solid impurities in the treated water 24. The treated water 24 from the bioreactor 16 is filtered in this sand filter 14 to produce a product water effluent 26 and a second reject 27. The first and second reject streams 22, 27 are combined and disposed of in sewage or other wastewater streams (not illustrated).

[0048] As shown Figure 1, the height of the bioreactor 16 is lower than the height of the first sand filter 12 and taller in the vertical dimension than the second sand filter 14 to allow for gravity flow of influent from the first sand filter 12 to the bioreactor 16 and then to sand filter 14. More specifically, the location of the influent inlet port 82 in the bioreactor 16 (Figure 3) is lower in elevation than the effluent discharge port 44 from the first sand filter 12 so that the effluent from the first sand filter 12 will flow by gravity through a connecting pipe into the inlet port 82 of the bioreactor 16. The effluent outlet port 89 from the bioreactor 16 is at a higher elevation than the inlet port 42A of the second (polishing) sand filter 14. The effluent will therefore flow by gravity to the inlet port 42A of the second sand filter 14.

[0049] In the overall process shown in Figure 1, the primary influent 42 to be treated in many applications undergoes a pretreatment step (not illustrated) to

selectively remove suspended solids. This pretreatment process provides an influent for the illustrated that results in an effluent of a desired purity suitable for a number of water reuse applications or disposal options.

[0050] Figure 2 illustrates the general construction and operation of sand filters 12 and 14 used as part of the wastewater treatment process 10 shown in Figure 1. Each of the sand filters 12 and 14 are continuous backwash upflow media (CBUM) filtration vessels having a similar in design as that described in United States Patent No. 6,462,005, the contents of which are to be incorporated into this specification by this reference. It should be understood that each of the features in the first sand filter 12 correspond with the features in the second sand filter 14. For the sake of clarity in Figure 1, features in the second sand filter 14 are differentiated to similar features in the first sand filter 12 by the addition of the letter A to the reference numerals.

[0051] Generally, each sand filter 12, 14 is a generally cylindrically shaped vessel 32 having a planar top end 36 and a funnel-shaped bottom portion 38. The vessel is filled with a filter medium, such as sand 70, from the bottom funnel-shaped portion 38 to a level generally indicated by the reference numeral 72. Each sand filter 12, 14 include an inlet port 42 through which untreated water/wastewater (influent) is introduced into the vessel 32 (indicated by arrow 48) and an outlet ports 44 through which effluent is discharged (indicated by arrow 50). Additionally, reject is discharged from the outlet port 46 as shown by arrow 52.

[0052] Influent introduced through the inlet port 42 flows a through a feed duct 54 to distribution arms 62 that extend radially from a riser 60 and is discharged into the vessel 32 as shown by arrows 68 to provide equal distribution within the sand media, and rises upwardly through the sand bed 70 in the vessel 32. Filtration of the influent takes place as the influent rises through the sand bed 70. Most of the suspended solids in the influent will be separated near the distribution arms 62.

[0053] A chemical coagulant, such as polyaluminium-chloride, is introduced into the influent at inlet 42 from a polymer tank 43 (Figure 1) using polymer pumps 45A and 45B (Figure 1). Within the sand bed 70, the coagulant forms a filtration gel layer that acts as a chemical and physical filter barrier separating contaminants from the water. As the water moves up through the vessel 32, suspended solids are trapped in the coagulant gel that is held in place by the sand bed.

[0054] The sand filter media and chemical barrier (also referred to as a polymer membrane) moves slowly downward in the vessel 32 as indicated by arrows 74. This results in the dirtiest portion of the filter medium continuing downwardly out of contact with the influent. The sand media continues to capture coagulant and contaminants as the media travels downward.

[0055] Sand is continuously moved from the bottom of the vessel 38 to the top of the vessel 36 through the use of an air-lift pump 76 that extends in the riser 60. This drives the slow downward movement of the sand media. Compressed air is supplied from air compressors 75A and 75B (Figure 1) to an airlift chamber at 76A of the air-lift pump 76 near the bottom of the riser 60 to move the sand media through an inlet 80 of the air-lift pump 76 (indicated by arrows 78) and up the riser 60. The dirty filter medium in the airlift pump 76 contains a mixture of the influent liquid, air and the filter medium. This mixture is subjected to mechanical agitation within the air-lift pump 76 causing the dirt to be separated from the grains of sand.

[0056] The sand is also washed in a washboard unit 82 located near the top of the vessel 32. The washboard unit 82 agitates and separates the sand from the coagulant/contaminant mixture. The cleaned sand media has a higher density and falls back into the vessel to the top of the moving sand bed 70. The reject from the washboard unit 82 flows through a discharge duct 84 and is discharged through the outlet port 46 as indicated by arrow 52. The treated water flows out of the sand near the top 36 of the vessel 32 as an overflow and is discharged as an effluent through the outlet port 44 indicated by the arrow 50 out of the vessel 32.

[0057] A number of process variables are monitored as control parameters for controlling the filtering characteristics and operation of sand filters 12, 14.

[0058] Firstly, the backpressure of the influent is monitored using a liquid level monitor 115 positioned at the inlet 42. A backpressure measurement is a measure of the permeability of the filtration gel layer (or chemical and physical filter barrier) comprised of the sand, coagulant and captured TSS. The variation in permeability measured as head pressure is due to the change in hydraulic conductivity caused by the increase or decrease in the amount of coagulant and TSS in the interstitial space between the sand grains restricting flow (hydraulic conductivity) as measured by the change in head pressure.

[0059] The liquid level monitor 115 senses the water level in the vertical pipe rising from inlet 42, providing a measure of backpressure at the inlet 42. A measurement signal from the level monitor 115 is processed by computer 118 and a control signal is then generated by the computer which is used to adjust the rate of air flow to airlift pump 76 via air flow rate controller 110 positioned in air inlet line 112. When the head pressure begins to increase, it is an indication that the solids inventory has begun to exceed the critical mass required for proper filtration results and a decrease in head pressure is an indication that the critical mass is below what is required. The airflow controller to the airlift pump 76 senses flow rate and adjusts the flow rate to maintain the proper level by a signal from a remote controller (not shown). The flow rate monitor requires only a limited pressure drop to function and provide real time data on operating rate.

[0060] This provides the ability for the vessel's sand movement to be increased or decreased as backpressure within the vessel 32 varies slowing or quickening the removal of the chemical and physical filter barrier within the sand media. The rate of air flow to airlift pump 76 is adjusted to maintain a target ratio range between the size of the solids inventory and the size of the sand bed 70 within the system of between 10 and 30 SCFH.

[0061] Further control over the filtering characteristics of the sand filters 12, 14 is provided by monitoring the contaminant value of the influent 20, 24 (Figure 1), and in some embodiments effluent 21, 26 (Figure 1) of the sand filters 12, 14 and using these measurements to control the proper level of the chemical and physical filter barrier within the vessels 32. This type of control is particularly useful during conditions of fluctuating influent quality.

[0062] In the illustrated embodiment, the turbidity of the influent 20, 24 (Figure 1) can be monitored using a turbidity meter (not shown) placed near the inlet 42, 42A of the respective sand filters 12, 14. A measurement signal from the turbidity meter is processed by computer 118 and a control signal is then generated by the computer 118 which is used to adjust the rate of air flow to airlift pump 76 via air flow rate controller 110 positioned in air inlet line 112. As detailed above, this provides the ability for the vessel's sand movement to be increased or decreased as backpressure within the vessel 32 varies slowing or quickening the removal of the chemical and physical filter barrier within the sand media. Again, the rate of air flow to airlift pump 76 is adjusted to maintain a target ratio range between the size of the solids inventory and the size of the sand bed 70 within the system of between 10 and 30 SCFH.

[0063] The turbidity of the effluent 21, 26 (Figure 1) can also be monitored and used as a control parameter for coagulant(s) addition to the influent of the sand filters 12, 14. Here, the turbidity of the effluent can be monitored using a turbidity meter (not illustrated) placed near the outlet 44, 44A of the sand filter 12, 14. A measurement signal from the turbidity meter is processed by computer 18 and a control signal is then generated by the computer used to adjust the amount of coagulants added to the influent. The amount of coagulants added to the influent changes the properties of the chemical and physical filter barrier within the sand media, thereby changing the filtering characteristics of the sand filter 12, 14. In some embodiments, the effluent turbidity measurement may also be used as a control parameter for adjusting the rate of air flow to airlift pump 76.

[0064] The data inputs for both influent back pressure (via liquid level monitor 115), influent turbidity (via the influent turbidity meter) and in some embodiments effluent turbidity (via the effluent turbidity meter) are logged and compared to historical information, including operating parameters of head pressure, turbidity, influent flow rate, coagulant (chemical polymer) usage, and air flow rate. This data is then used to continually make the alterations to air inflow that in turn increases or decreases the movement of the sand filter bed to produce acceptable effluent quality.

[0065] In addition, the coagulant flow rate can be varied by computer control to establish during commissioning the proper baseline level of chemical and physical filter barrier within the vessel. In some embodiments, the effluent turbidity value is displayed on a computer screen. The amount of coagulation and/or flocculation can then be adjusted by sending a computer signal to a dose rate pump to change the amount of polymer injected into the influent.

[0066] Figure 3 provides a more detailed view of the bioreactor 16 of the influent treatment process 10 shown in Figure 1. The illustrated bioreactor 16 is a cylindrical vessel 81. In Figure 1, this vessel is supported by a stand assembly 93 that includes a funnel-shaped bottom portion 94. The stand assembly 93 and includes a funnel-shaped bottom portion 94 not shown in Figure 3. It should be appreciated that the vessel 81 could have other shapes, such as a generally cylindrical shape. The volume of the bioreactor 16 is selected to suit the volume of material to be treated for a certain time period. The vessel 81 is constructed with a closed top 83 sealed to the atmosphere except for the vent process 88 at the top of the vessel required to release nitrogen gas. A closed and locked manway 84 is provided for access into the bioreactor 16 for use in the addition of materials or maintenance.

[0067] The illustrated bioreactor 16 includes polyvinyl alcohol (PVA) hydrogel biomass carrier beads or balls populated with immobilized bacteria. It should be appreciated that in other embodiments, the bacteria used for the process may be located on or within other structures other than PVA beads/balls in the reactor. Both ammonium oxidizing bacteria (*Nitrosomonas* spp.) and anaerobic

ammonium oxidizing (anammox) bacteria can be used in the bioreactor. These bacteria use ammonium as electron donor and nitrite as electron acceptor without the production of nitrate. In the illustrated embodiment, the bacteria culture is predominantly anammox as the specific ammonium and nitrite removal rates of anammox bacteria are generally significantly faster than those of *Nitrosomonas* spp1.

[0068] The bacteria containing PVA hydrogel beads/balls have negative buoyancy which causes the balls to sink to the bottom of the reactor 16 whenever the balls are not within an upward flow current 91. Movement of the hydrogel beads/balls by the effluent current flow 91 increases mixing and availability of bacteria throughout the reactor for ammonia and nitrite removal. In some embodiments, baffles (not shown) may also be installed in the reactor to segregate the hydrogel beads/balls into various sized quadrants. The size, configuration and architecture of the beads/balls are ideally configured for each specific apparatus and/or fluid treatment application.

[0069] After treatment in the first sand filter 12, the effluent/filtered water 21 is delivered to the bioreactor 12 with low carbon content. The effluent from the first sand filter 13 flows by gravity through a pipe 85 to the bottom of the bioreactor 16 and exits through several outlet holes or nozzles 86 that may be in the form of a manifold process. This provides a constant upflow of filtered water 21 into the vessel 81. The size and location of the outlet holes 86 are ideally configured to minimize backpressure while maximizing the upward flow velocity 91 and mixing action of the influent.

[0070] The filtered water 21 is also maintained in a low oxygen (anoxic) zone with typical dissolved oxygen levels between 0.7 and 1.5 mg/L. The reduced level of dissolved oxygen (DO) is designed to provide a starved bed condition with a low concentration of available carbon, providing an environment that cultivates the use of ammonium ( $\text{NH}_4^+$ ) and nitrite ( $\text{NO}_2^-$ ) for the bacteria to feed upon, rather than providing oxygen for nitrification and carbon for denitrification. Here the water is mixed with a bacteria culture to break down the ammonia and other nitrogen components to nitrogen gas and water. For each specific

application, the reactor is sized based on a determination of contact time required for the removal of the nitrogen compounds from the filtered water.

[0071] Operation of the illustrated bioreactor 16 is controlled. The control system of the illustrated bioreactor 16 includes a dissolved oxygen sensor 87 stationed near the middle of the bioreactor 16. The dissolved oxygen sensor 87 is used to monitor the oxygen level in the bioreactor 16. A computer 18 monitors the level of dissolved oxygen using a measurement signal sent from the dissolved oxygen sensor 87. The computer 18 sends a control signal to a mass flow controller 10 to provide diffused air to the bioreactor 16 when the dissolved oxygen level drops below 0.7 mg/L. An air tube 92 from the air compressor that provides compressed air to the two sand filters 12, 14 supplies this additional oxygen to the bioreactor. The air tube 92 is connected to the influent pipe near the influent port 82 entrance to the bioreactor 16. A non return valve is provided to prevent water from entering the air supply tube 92. The controller maintains the dissolved oxygen level of the bioreactor between 0.7 and 1.5 mg/L.

[0072] Those skilled in the art will appreciate that the invention described herein is susceptible to variations and modifications other than those specifically described. It is understood that the invention includes all such variations and modifications which fall within the spirit and scope of the present invention.

[0073] Where the terms "comprise", "comprises", "comprised" or "comprising" are used in this specification (including the claims) they are to be interpreted as specifying the presence of the stated features, integers, steps or components, but not precluding the presence of one or more other feature, integer, step, component or group thereof.

**Claims**

1. An automated method of controlling the filtering characteristics of a continuous upflow granular media filter in which a liquid that includes impurities is fed as an influent and a treated liquid is produced as an effluent, the granular media filter including a media filter bed and an airlift pump that moves granular media from a removal point in the media filter bed to a deposit point in the media filter bed, the method comprising the steps of:

monitoring the impurities level of the influent;

converting the influent impurities level into an impurities signal input to a computer, which uses computer software to interpret the impurities signal input; and

using the impurities signal to control the air inflow rate to the airlift pump to maintain a target ratio range between the size of captured solids inventory of the granular media filter and the size of the media filter bed of the granular media filter.

2. An automated method according to claim 1, wherein the impurities level of the influent is provided by a turbidity measurement.

3. An automated method according to claim 1 or 2, in which at least one coagulant is added to the influent, and wherein the method further includes the steps of:

monitoring the impurities level of the effluent;

converting the effluent impurities level into a dose signal input to a computer which uses computer software to interpret the dose signal; and

using the dose signal to control the amount of coagulants added to the influent stream and thereby maintain a target ratio between the size of captured solids inventory of the granular media filter and the size of the media filter bed of the granular media filter.

4. An automated method according to claim 3, wherein the impurities level of the effluent is provided by turbidity measurement.

5. An automated method according to any one of claims 1 to 4, further including:

monitoring an inflow head pressure at an influent inlet of the continuous upflow granular media filter;

converting the head pressure into a pressure signal input to a computer which uses computer software to interpret the pressure signal; and

using the pressure signal to control the air inflow rate to the airlift pump to maintain a target ratio range between the size of captured solids inventory of the granular media filter and the size of the media filter bed of the granular media filter.

6. A process for treating a liquid that includes impurities, including:

a first continuous upflow granular media filter in which the liquid is fed as a first influent and treated to produce a first effluent and a first reject, the first granular media filter including a media filter bed and an airlift pump that moves granular media from a removal point in the media filter bed to a deposit point in the media filter bed;

an influent impurities meter at an inlet for the influent of the first continuous upflow granular media filter; and

a control system operatively linked to the influent impurities meter which controls the operation of the airlift pump in the first continuous upflow granular media filter to maintain a target ratio range between the size of captured solids inventory of the first granular media filter and the size of the media filter bed of the first granular media filter.

7. A process according to claim 6, wherein the influent impurities meter is a turbidity meter.

8. A process according to claim 6 or 7, wherein at least one coagulant is added to the first influent prior to the first influent being fed into the first continuous upflow granular media filter, and the process further includes:

an effluent impurities meter at an outlet for the effluent of the first continuous upflow granular media filter; and

a control system operatively linked to the effluent impurities meter which controls the operation of coagulation chemical addition to the first granular media filter to maintain a target ratio range between the size of captured solids inventory of the first granular media filter and the size of the media filter bed of the first granular media filter.

9. A process according to claim 8, wherein the effluent impurities meter is a turbidity meter.

10. A process according to any one of claims 6 to 9, further including a bioreactor in which the first effluent is fed as a second influent and treated to substantially remove the nitrogen content thereof to produce a second effluent.

11. A process according to any one of claims 6 to 10, wherein the bioreactor comprises a closed vessel having a low oxygen (anoxic) environment and a flexible media bed housing nitrogen removal bacteria.

12. A process according to any one of claims 10 or 11, further including:  
a dissolved oxygen sensor to monitor the dissolved oxygen level in the bioreactor; and

a control system operatively linked to the dissolved oxygen sensor, the control system introducing further oxygen into the bioreactor when the dissolved oxygen level drops below a desired set point.

13. A process according to claim 12, wherein the controller maintains the dissolved oxygen levels between 0.7 and 1.5 mg/L.

14. A process according to any one of claims 6 to 13, further including:  
a head pressure detector for monitoring an inflow head pressure at a first influent inlet of the first continuous upflow granular media filter; and  
a control system operatively linked to the head pressure detector which controls the operation of an airlift pump in the first continuous upflow granular media filter to maintain a target ratio range between the size of captured solids

inventory of the first granular media filter and the size of the media filter bed of the first granular media filter.

15. A process according to any one of claims 6 to 14, wherein sand is used as a filter medium in the first continuous upflow granular media filter.

16. A process according to any one of claims 6 to 15, further including:  
a second continuously operated granular media filter in which the second effluent is fed as a third influent and treated to produce a third effluent and a second reject, the second granular media filter including a media filter bed and an airlift pump that moves granular media from a removal point in the media filter bed to a deposit point in the media filter bed.

17. A process according to claim 16, further including:  
an influent impurities meter at the influent intake of the second continuous upflow granular media filter; and  
a control system operatively linked to the influent impurities meter which controls the operation of the airlift pump in the second continuous upflow granular media filter to maintain a target ratio range between the size of captured solids inventory of the granular media filter and the size of the media filter bed of the granular media filter.

18. A process according to claim 16 or 17, in which coagulants are added to the third influent prior to the third influent being fed into the second continuous upflow granular media filter, the process further including:  
an effluent impurities meter at the effluent outlet of the second continuous upflow granular media filter; and  
a control system operatively linked to the effluent impurities meter which controls the operation of coagulation chemical addition to the second continuous upflow granular media filter to maintain a target ratio range between the size of captured solids inventory of the granular media filter and the size of the media filter bed of the second granular media filter.

19. A process according to claim 16, 17 or 18, further including:

a head pressure detector for monitoring an inflow head pressure at an inlet of the influent of the second continuous upflow granular media filter; and

a control system operatively linked to the head pressure detector which controls the operation of an airlift pump in the second continuous upflow granular media filter to maintain a target ratio range between the size of captured solids inventory of the granular media filter and the size of a granular media filter bed of the second granular media filter.

20. The process any one of claims 16 to 19, wherein sand is used as a filter medium in the second continuous upflow granular media filter.

21. A process according to any one of claims 6 to 20, further including at least one solid separation apparatus in which the liquid undergoes a solid separation step to selectively remove suspended solids therefrom prior to being fed into the first continuously operated granular media filter.

22. A system for treating a liquid having impurities therein, including:  
a first continuous upflow granular media filter in which the liquid is fed as a first influent and treated to produce a first effluent and a first reject; and  
a bioreactor in which the first effluent is fed as a second influent and treated to substantially remove the nitrogen content thereof to produce a second effluent.

23. A system according to claim 22, further including:  
a second continuously operated granular media filter in which the second effluent is fed as a third influent and treated to produce a third effluent and a second reject.

24. A system for treating a liquid according to claim 22 or 23, including a process according to any one of claims 6 to 21.

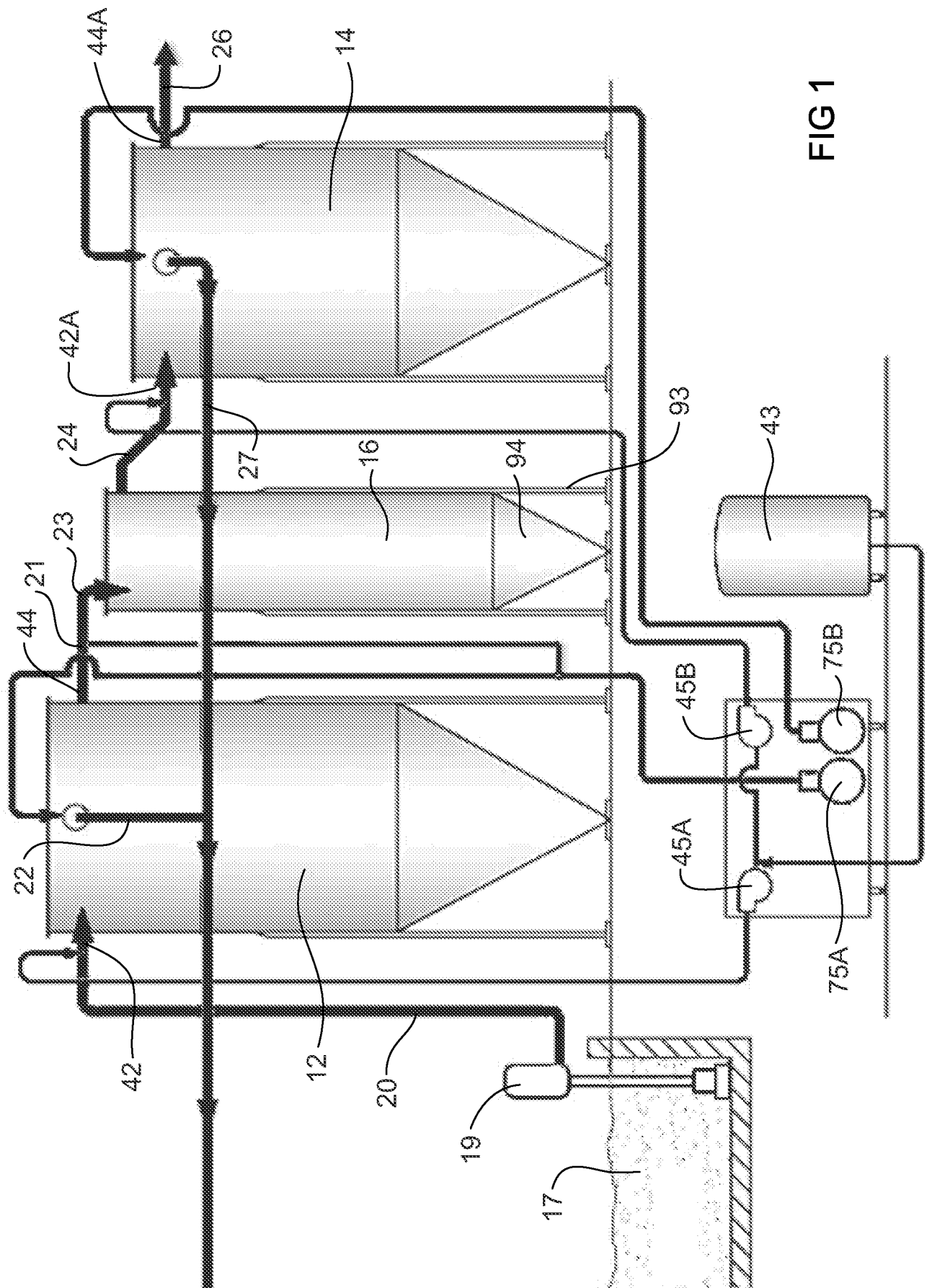
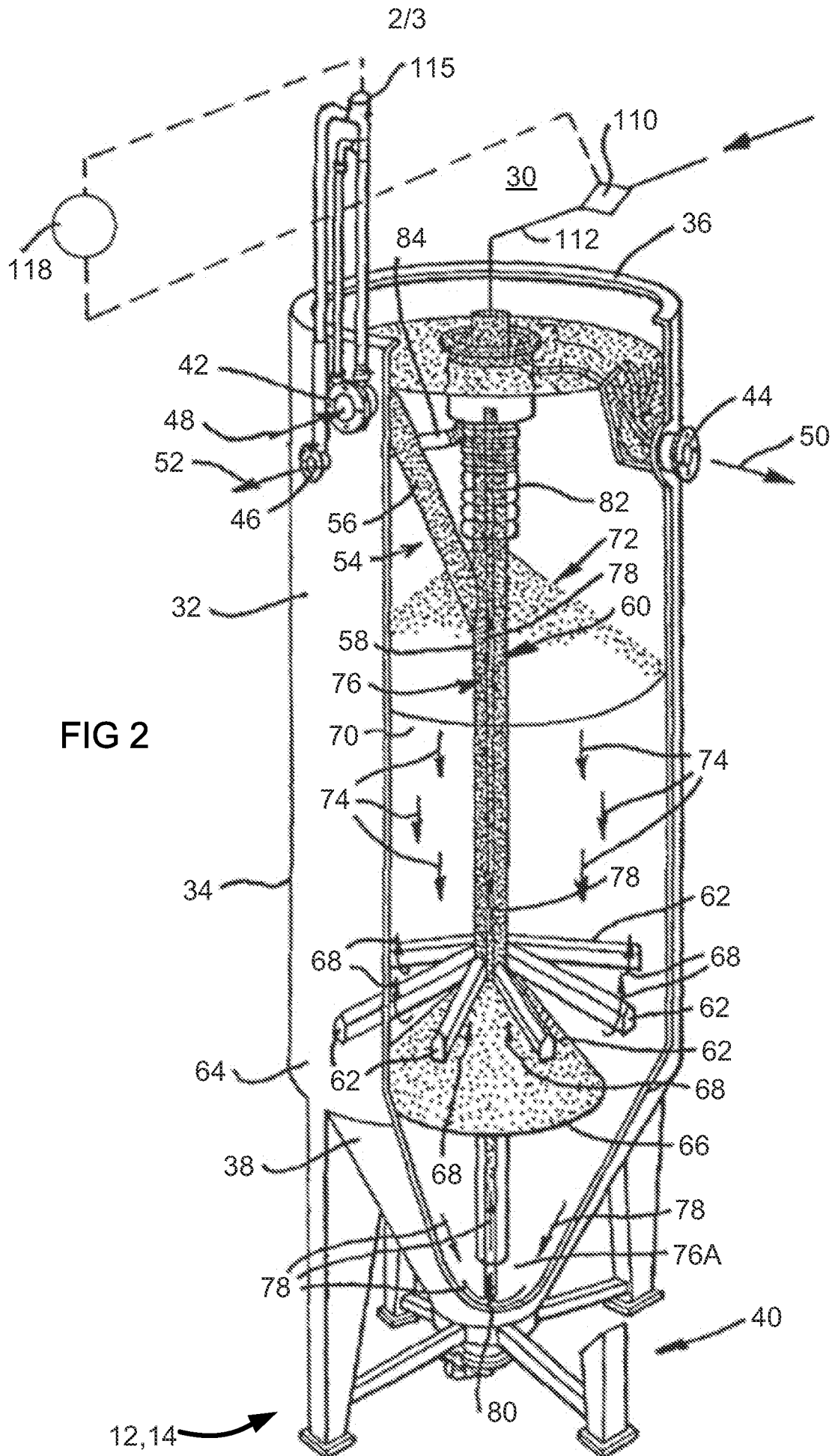


FIG 1



3/3

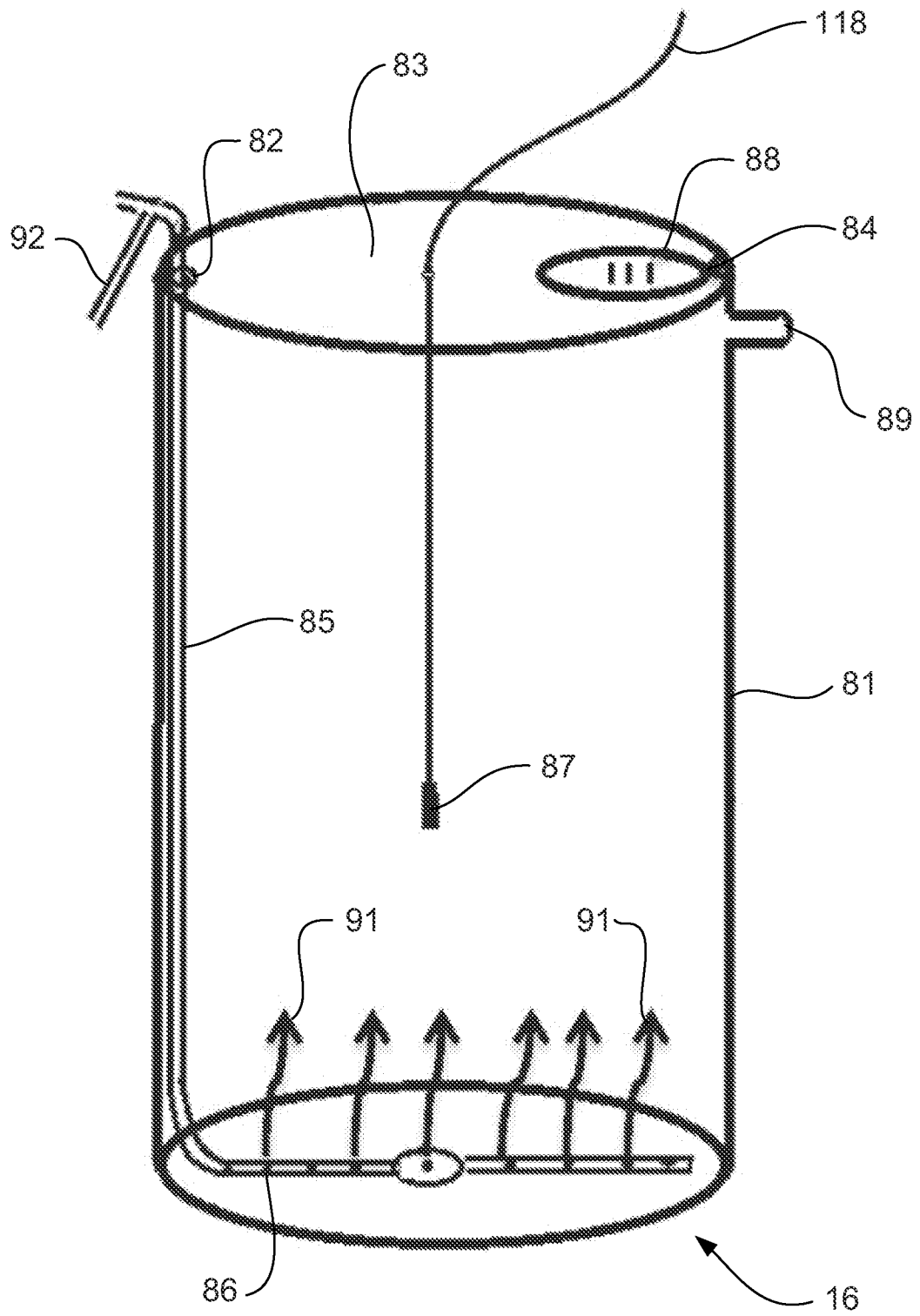


FIG 3

## INTERNATIONAL SEARCH REPORT

International application No.

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| A. CLASSIFICATION OF SUBJECT MATTER                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                        |                                                                   |
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| B01D 24/16 (2006.01) B01D 24/26 (2006.01) B01D 33/00 (2006.01)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                        |                                                                   |
| According to International Patent Classification (IPC) or to both national classification and IPC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                        |                                                                   |
| B. FIELDS SEARCHED                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                        |                                                                   |
| Minimum documentation searched (classification system followed by classification symbols)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                        |                                                                   |
| Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                        |                                                                   |
| Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)<br>EPODOC & WPI with IPC (B01D24/16/LOW/IC/EC OR B01D24/26/LOW/IC/EC OR B01D33/IC/EC, C02F1/IC/EC, C02F9/14/LOW/IC/EC) and Keywords (FILT+, CONTROL+, AIR_LIFT+, SAND+, ANOXIC+, ANAEROB+, AND SIMILAR TERMS); ESP@CENET with IPC B01D24/16, B01D24/26, B01D33, C02F1, C02F9/14 and Keywords (CONTROL+, AIRLIFT+, SAND+, NITROGEN+, ANOXIC+, ANAEROB+, AND SIMILAR TERMS); GOOGLE PATENT with Keywords (LIQUID, TREATMENT, SAND, FILTER, CONTROL, AIRLIFT, NITROGEN REMOVAL, ANOXIC, ANAEROBIC, GRANULE AND SIMILAR TERMS)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                        |                                                                   |
| C. DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                        |                                                                   |
| Category*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Citation of document, with indication, where appropriate, of the relevant passages                                     | Relevant to claim No.                                             |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | US 5843308 A (SUOZZO ET AL.) 1 December 1998<br>Abstract                                                               | 1 - 24                                                            |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | US 5277829 A (WARD) 11 January 1994<br>Abstract                                                                        | 1 - 24                                                            |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | US 6319413 B1 (XIA ET AL.) 20 November 2001<br>Abstract                                                                | 1 - 24                                                            |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | CN 200967775 Y (UNIV NANJING NORMAL [CN]) 31 October 2007. English abstract retrieved from EPODOC database<br>Abstract | 1 - 24                                                            |
| <input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C <input checked="" type="checkbox"/> See patent family annex                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                        |                                                                   |
| * Special categories of cited documents:<br>"A" document defining the general state of the art which is not considered to be of particular relevance<br>"E" earlier application or patent but published on or after the international filing date<br>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)<br>"O" document referring to an oral disclosure, use, exhibition or other means<br>"P" document published prior to the international filing date but later than the priority date claimed<br>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention<br>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone<br>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art<br>"&" document member of the same patent family |                                                                                                                        |                                                                   |
| Date of the actual completion of the international search<br>14 May 2012                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                        | Date of mailing of the international search report<br>14 May 2012 |

|                                                                                                                                                                                        |                                                                                                                                                |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| Name and mailing address of the ISA/AU<br>AUSTRALIAN PATENT OFFICE<br>PO BOX 200, WODEN ACT 2606, AUSTRALIA<br>E-mail address: pct@ipaustralia.gov.au<br>Facsimile No. +61 2 6283 7999 | Authorized officer<br><b>MILKA WENAS</b><br>AUSTRALIAN PATENT OFFICE<br>(ISO 9001 Quality Certified Service)<br>Telephone No : +61 2 6283 2593 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2012/000204

| C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                                          |                       |
|-------------------------------------------------------|----------------------------------------------------------------------------------------------------------|-----------------------|
| Category*                                             | Citation of document, with indication, where appropriate, of the relevant passages                       | Relevant to claim No. |
| A                                                     | CN 201415964 Y (YUANGANG CHEN) 3 March 2010. English abstract retrieved from EPODOC database<br>Abstract | 1 – 24                |

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2012/000204

**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

Please see Supplemental Box 1

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

**Remark on Protest**

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

**Supplemental Box 1**

(To be used when the space in any of Boxes I to IV is not sufficient)

**Continuation of Box No: III**

This International Application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept.

This Authority has found that there are different inventions based on the following features that separate the claims into distinct groups:

- Claims 1 – 21 are directed to an automated method of controlling the filtering characteristics of a continuous upflow granular media filter in which a liquid that includes impurities is fed as an influent and a treated liquid is produced as an effluent, *the granular media filter including a media filter bed and an airlift pump that moves granular media from a removal point in the media filter bed to a deposit point in the media filter bed, the method comprising the steps of: monitoring the impurities level of the influent; converting the influent impurities level into an impurities signal input to a computer, which uses computer software to interpret the impurities signal input; and using the impurities signal to control the air inflow rate to the airlift pump to maintain a target ratio range between the size of captured solids inventory of the granular media filter and the size of the media filter bed of the granular media filter.* Furthermore, these claims are directed to a process for treating a liquid that includes impurities, including: a first continuous upflow granular media filter in which the liquid is fed as a first influent and treated to produce a first effluent and a first reject, *the first granular media filter including a media filter bed and an airlift pump that moves granular media from a removal point in the media filter bed to a deposit point in the media filter bed; an influent impurities meter at an inlet for the influent of the first continuous upflow granular media filter; and a control system operatively linked to the influent impurities meter which controls the operation of the airlift pump in the first continuous upflow granular media filter to maintain a target ratio range between the size of captured solids inventory of the first granular media filter and the size of the media filter bed of the first granular media filter.* The above feature is specific to this group of claims.
- Claims 22 – 24 are directed to a system for treating a liquid having impurities therein, including: a first continuous upflow granular media filter in which the liquid is fed as a first influent and treated to produce a first effluent and a first reject; and *a bioreactor in which the first effluent is fed as a second influent and treated to substantially remove the nitrogen content thereof to produce a second effluent.* The above feature is specific to this group of claims.

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

When there is no special technical feature common to all the claimed inventions there is no unity of invention.

In the above groups of claims, the identified features may have the potential to make a contribution over the prior art but are not common to all the claimed inventions and therefore cannot provide the required technical relationship. Therefore there is no special technical feature common to all the claimed inventions and the requirements for unity of invention are consequently not satisfied *a priori*.

## INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2012/000204

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

| Patent Document Cited in<br>Search Report                                                                                 |           |      | Patent Family Member |    |            |    |            |
|---------------------------------------------------------------------------------------------------------------------------|-----------|------|----------------------|----|------------|----|------------|
| US                                                                                                                        | 5843308   | AU   | 51042/98             | BR | 9706917    | CA | 2242156    |
|                                                                                                                           |           | EP   | 0881927              | WO | 9819766    |    |            |
| US                                                                                                                        | 5277829   | AU   | 42318/93             | AU | 79273/94   | BR | 9306735    |
|                                                                                                                           |           | CA   | 2140245              | EP | 0650389    | FI | 950161     |
|                                                                                                                           |           | MX   | 9304234              | NO | 950131     | NZ | 252523     |
|                                                                                                                           |           | US   | 5520804              | US | 5622458    | US | 5727908    |
|                                                                                                                           |           | WO   | 9401194              | WO | 9511070    |    |            |
| US                                                                                                                        | 6319413   | AU   | 53743/01             | CA | 2406280    | MX | PA02010376 |
|                                                                                                                           |           | US   | 2002036164           | US | 6517712    | US | 2003066792 |
|                                                                                                                           |           | US   | 6641737              | US | 2004050762 | US | 6790351    |
|                                                                                                                           |           | WO   | 0180966              |    |            |    |            |
| CN                                                                                                                        | 200967775 | NONE |                      |    |            |    |            |
| CN                                                                                                                        | 201415964 | NONE |                      |    |            |    |            |
| Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. |           |      |                      |    |            |    |            |
| END OF ANNEX                                                                                                              |           |      |                      |    |            |    |            |