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(71) Applicant: **AUSTRALIAN WATERSECURE INNOVATIONS LTD** [AU/AU]; c/o- Fisher Adams Kelly Callinans, Level 6, 175 Eagle Street, Brisbane, Queensland 4000 (AU).

(72) Inventors: **SCALES, Peter J.**; co- Fisher Adams Kelly Callinans, Level 6, 175 Eagle Street, Brisbane, Queensland 4000 (AU). **NORTHCOTT, Kathy Anne**; co- Fisher Adams Kelly Callinans, Level 6, 175 Eagle Street, Brisbane, Queensland 4000 (AU). **GRAY, Stephen Richard**; co- Fisher Adams Kelly Callinans, Level 6, 175 Eagle Street, Brisbane, Queensland 4000 (AU).

(74) Agent: **FISHER ADAMS KELLY CALLINANS**; Level 6, 175 Eagle Street, Brisbane, Queensland 4000 (AU).

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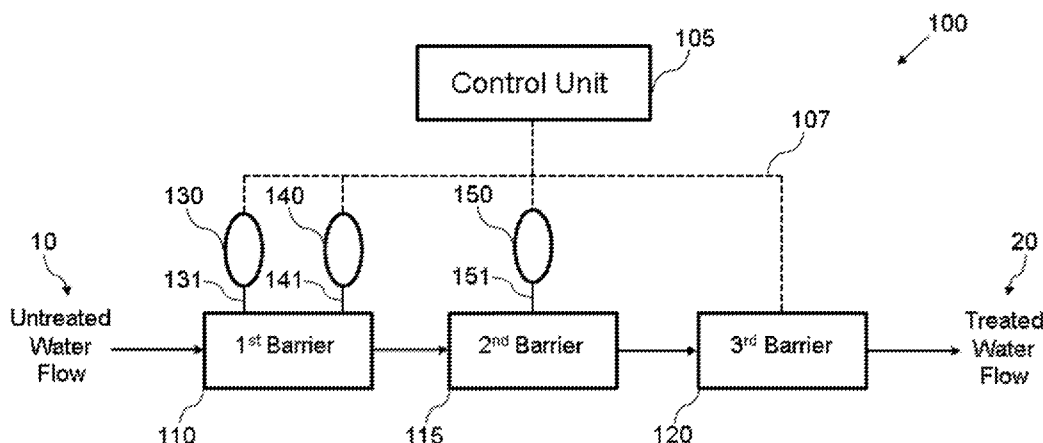
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(54) Title: WATER TREATMENT SYSTEM

FIG. 1



(57) Abstract: An improved water treatment system for producing a treated water flow. The system includes: a control unit; a first barrier for receiving a feed water flow therethrough and operable to remove one or a plurality of chemical agents and one or a plurality of biological agents therefrom; and one or more sensors adapted to measure one or more performance indicators of said first barrier, the sensors further adapted for inputting the performance indicators to the control unit; wherein the control unit is adapted to access information for facilitating correlation of the measured performance indicators with a level of removal of the chemical agents and simultaneously a level of removal of the biological agents.



TITLE

WATER TREATMENT SYSTEM

FIELD OF THE INVENTION

[001] The present invention relates to a system and method of treating water. In particular, although not exclusively, the invention relates to a system and method for monitoring the treating of wastewater by simultaneously removing one or more biological agents and one or more chemical agents.

BACKGROUND TO THE INVENTION

[002] A key hindrance to the reuse or recycling of water is the cost of compliance testing and process validation associated with ensuring that biological agents and chemical agents in the feedwater are removed to a level that ensures no acute or chronic health and/or environmental effects from the reuse of the water and the treated water is aesthetically pleasing in terms of taste and odour. In line with this guideline, a biological agent may be a pathogenic agent in the form of a virus, bacteria, protozoa or helminth or simply a microbial agent with the propensity to cause aesthetic nuisance to the taste and odour of the treated water. In the case of pathogens, compliance entities have specified guidelines for a number of process barriers for the minimum log removal of pathogens. An example is the USEPA Long Term 2 Enhanced Surface Water Treatment Rule for the removal of *Cryptosporidium* as exemplified by Brown [1]. This validation is deemed compliant by regulatory bodies provided that the equipment associated with the barrier is operated in a consistent manner and continuous or semi-continuous monitoring of surrogates or indirect indicators to performance are maintained. The process allows the barrier to be operated using, for example, conductivity measurement as an indicator of barrier integrity in the case of a reverse osmosis (RO) membrane. This process significantly reduces the need for continuous or semi-continuous microbial analysis for which comprehensive on-line continuous monitoring is not available. This in turn reduces the cost of fit for purpose water production.

[003] In addition to biological agents, there are a large number of chemicals that find their way into our waterways and waste water and the number and diversity is increasing year on year. Many national regulatory authorities now publish guidelines for the maximum recommended concentrations of chemicals of concern (CoC) deemed to be of potential risk in causing acute or chronic illness. These guidelines usually classify the chemicals into end use categories and there are in excess of three hundred CoC listed in, for instance, the Australian Guidelines for Water Recycling and Australian Drinking Water Guidelines [2, 3]. The list can never be comprehensive in an environment where upwards of 50,000 chemicals and their metabolites are common to many cities.

[004] To try and circumvent the issue, regulatory authorities associated with recycling water or just treating water for potable applications often use a surrogate list of CoC [4, 5]. An inability to measure these chemicals on-line, however, has meant that whilst parameters such as total organic carbon (TOC) in the product water have been used as an indicator of process performance, the true risk of an individual chemical moving through a barrier has not been incorporated into a continuous or semi-continuous monitoring approach similar to that for biological agents. As a result, regular and expensive product water analyses for a range of chemical species continues.

[005] Accordingly, there remains a need for a system of treating water that includes at least semi-continuous monitoring of indirect indicators of the performance of one or more barriers with respect to the removal of chemicals together with biological agents in the feed water thereof.

OBJECT OF THE INVENTION

[006] It is an object of the present invention to overcome and/or alleviate one or more of the disadvantages of the prior art or provide the consumer with a useful or commercial choice.

SUMMARY OF THE INVENTION

[007] In one aspect, although not necessarily the only aspect or the broadest aspect, the invention resides in a water treatment system for producing a treated water flow comprising;

a control unit;

a first barrier for receiving a feed water flow therethrough and operable to remove one or a plurality of chemical agents and one or a plurality of biological agents therefrom;

one or more sensors adapted to measure one or more performance indicators of said first barrier, the sensors further adapted for inputting the performance indicators to the control unit;

wherein the control unit is adapted to access information for facilitating correlation of the measured performance indicators with a level of removal of the chemical agents and simultaneously a level of removal of the biological agents in the treated water flow.

[008] In certain embodiments, the system of the present aspect comprises a first sensor adapted to measure a first performance indicator of said first barrier, wherein the control unit is adapted to correlate the first performance indicator with the level of removal of the chemical agents and the level of removal of the biological agents in the treated water flow. In alternative embodiments, the system of the present aspect comprises a first sensor adapted to measure a first performance indicator of said first barrier and a second sensor adapted to measure a second performance indicator of said first barrier, wherein the control unit is adapted to correlate: (i) the first performance indicator with the level of removal of the chemical agents; and (ii) the second performance indicator with the level of removal of the biological agents.

[009] Suitably, the first barrier is selected from the group consisting of a reverse osmosis unit, an ozonation unit, a UV/peroxide unit, a chemical oxidation unit, an ion exchange bed unit, an activated carbon bed unit, a membrane bioreactor unit, an activated sludge unit and any combination thereof. In particular preferred embodiments, the first barrier is or comprises:

(i) the reverse osmosis unit and the performance indicators are selected from the group consisting of a level of solution conductivity, a

pressure decay test level, a residual carbon level, a sulphate level and any combination thereof;

(ii) the ozonation unit and the performance indicators are selected from the group consisting of a residual ozone concentration, a ozone dose level, a contact time and any combination thereof ;

(iii) the UV/peroxide unit and the performance indicators are selected from the group consisting of a UV dose, a peroxide dose, a residual carbon level and any combination thereof;

(iv) the chemical oxidation unit and of a solution Eh level, an oxidant dose, a colour level and any combination thereof;

(v) the ion exchange unit and the performance indicators are selected from the group consisting of a UV absorbance level, a residual turbidity level, a residual carbon level, a fluorescence level and any combination thereof;

(vi) the activated carbon bed unit and the performance indicators are selected from the group consisting of a UV absorbance level, a residual turbidity level, a residual carbon level, a fluorescence level and any combination thereof;

(vii) the membrane bioreactor unit and the performance indicators are selected from the group consisting of a residual turbidity level, a residual carbon level, a nitrogen level, a phosphorus level and any combination thereof; and/or,

(viii) the activated sludge unit and the performance indicators are selected from the group consisting of a residual turbidity level, a residual carbon level, a nitrogen level, a phosphorus level and any combination thereof.

[0010] In one embodiment, the system further comprises a second barrier for receiving a feed water flow therethrough and operable to remove one or a plurality of biological agents therefrom. Preferably, the second barrier is selected from the group consisting of a microfiltration unit, a nanofiltration unit, a chlorination unit, a UV unit and any combination thereof.

[0011] In one embodiment, the system further comprises a third sensor adapted to measure a third performance indicator of the second barrier, the third sensor further adapted for inputting the third performance indicator to the

control unit, wherein the control unit is adapted to correlate the third performance indicator with the level of removal of the one or plurality of biological agents.

[0012] In particular embodiments, the system of the present aspect further comprises a third barrier selected from the group consisting of a biologically activated carbon unit, a calcite filter unit and any combination thereof.

[0013] In one embodiment, the sensors provide real-time and/or at least semi-continuous measurement of the performance indicators to the control unit.

[0014] Suitably, the control unit is further adapted to compare the performance indicators with a threshold level to identify a change in function of the first barrier and/or the second barrier and generate a control trigger point in accordance with the change. Preferably, the control unit generates an alert if the performance indicators are above or below the threshold level. In particular embodiments, the threshold level is determined at least in part by a molecular characteristic of the one or plurality of chemical agents and/or a microbial characteristic of the one or plurality of biological agents.

[0015] Suitably, the first, second and/or third barriers are designated as a critical control point in the water treatment system.

[0016] According to an alternative aspect, the invention resides in a method for operating a water treatment system to produce a treated water flow, including the steps of:

- providing the water treatment system comprising a control unit, a first barrier and one or more sensors;

- passing a feed water flow through the barrier to remove one or a plurality of chemical agents and one or a plurality of biological agents therefrom;

- measuring one or more performance indicators of the barrier by the one or more sensors;

- inputting the one or more performance indicators measured by the sensors into the control unit; and,

- correlating the one or more performance indicators by the control unit to a level of removal of the one or plurality of chemical agents and a level of removal of the one or plurality of biological agents.

[0017] In referring to the above aspects, the first barrier is suitably selected from the group consisting of a reverse osmosis unit, an ozonation unit, a UV/peroxide unit, a chemical oxidation unit, an ion exchange bed unit, an activated carbon bed unit, a membrane bioreactor unit, an activated sludge unit and any combination thereof. In particular preferred embodiments, the first barrier is or comprises:

(i) the reverse osmosis unit and the performance indicators are selected from the group consisting of a level of solution conductivity, a pressure decay test level, a residual carbon level, a sulphate level and any combination thereof;

(ii) the ozonation unit and the performance indicators are selected from the group consisting of a residual ozone concentration, a ozone dose level, a contact time and any combination thereof;

(iii) the UV/peroxide unit and the performance indicators are selected from the group consisting of a UV dose, a peroxide dose, a residual carbon level and any combination thereof;

(iv) the chemical oxidation unit and of a solution Eh level, an oxidant dose, a colour level and any combination thereof;

(v) the ion exchange unit and the performance indicators are selected from the group consisting of a UV absorbance level, a residual turbidity level, a residual carbon level, a fluorescence level and any combination thereof;

(vi) the activated carbon bed unit and the performance indicators are selected from the group consisting of a UV absorbance level, a residual turbidity level, a residual carbon level, a fluorescence level and any combination thereof;

(vii) the membrane bioreactor unit and the performance indicators are selected from the group consisting of a residual turbidity level, a residual carbon level, a nitrogen level, a phosphorus level and any combination thereof; and/or,

(viii) the activated sludge unit and the performance indicators are selected from the group consisting of a residual turbidity level, a residual carbon level, a nitrogen level, a phosphorus level and any combination thereof.

[0018] In particular embodiments, the water control system comprises a first sensor adapted to measure a first performance indicator of said first barrier, wherein the control unit correlates the first performance indicator to the level of removal of the chemical agents and the level of removal of the biological agents.

[0019] In alternative embodiments, the water control system comprises a first sensor adapted to measure a first performance indicator of said first barrier; and a second sensor adapted to measure a second performance indicator of said first barrier, wherein the control unit correlates: (i) the first performance indicator to the level of removal of the chemical agents; and (ii) the second performance indicator to the level of removal of the biological agents.

[0020] Suitably, the step of measuring the one or more performance indicators is performed by the sensors in a real-time and/or at least semi-continuous manner.

[0021] In particular embodiments, the method of the present aspect further includes the step of comparing the performance indicators with a threshold level by the control unit to identify a change in function of the barrier. Preferably, the control unit generates an alert if the performance indicators are above or below the threshold level whereby the most conservative scenario of performance relative to chemical or biological agent removal is dominant in the control hierarchy.

[0022] In one embodiment, the method of the present aspect further includes the step of generating a trigger control point in accordance with the change in function of the barrier.

[0023] Suitably, the threshold level is determined at least in part by a molecular characteristic of the one or plurality of chemical agents and/or a microbial characteristic of one or plurality of biological agents.

[0024] Further features of the invention will become apparent from the detailed description below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] To assist in understanding the invention and to enable a person skilled in the art to put the invention into practical effect, preferred embodiments of the invention will be described by way of example only with reference to the accompanying drawings, in which:

FIG. 1 is a schematic diagram of an embodiment of a water treatment system of the present invention;

FIG. 2 illustrates a method for operating a water treatment system to produce a treated water flow, according to an embodiment of the present invention;

FIG. 3 is a schematic diagram of an embodiment of a water treatment system of the present invention;

FIG. 4 illustrates typical LRV and ozone contact time (CT) levels over time of the ozonation unit in the operational plant (Circles identify > LRV where the feed concentrations were >2419.6 MPN/100 ml) where MPN is the Most Probable Number; and

FIG. 5 illustrates typical LRVs calculated from conductivity measurements of the feed and permeate of the reverse osmosis unit in the operational plant.

DETAILED DESCRIPTION OF THE INVENTION

[0026] The present invention relates to a system and method for monitoring the treating wastewater for simultaneously removing one or more biological agents and one or more chemical agents. Elements of the invention are illustrated in concise outline form in the drawings, showing only those specific details that are necessary to understand the embodiments of the present invention, but so as not to provide excessive detail that will be obvious to those of ordinary skill in the art in light of the present description.

[0027] In this specification, adjectives such as first and second, top and bottom and the like may be used solely to distinguish one element or action from another element or action without necessarily requiring or implying any actual such relationship or order. Words such as “comprises” or “includes” are intended to define a non-exclusive inclusion, such that a method or

apparatus that comprises a list of elements does not include only those elements but may include other elements not expressly listed, including elements that are inherent to such a method or system.

[0028] According to a first aspect, the present invention is defined as a water treatment system for producing a treated water flow comprising;

a control unit;

a first barrier for receiving a feed water flow therethrough and operable to remove one or a plurality of chemical agents and one or a plurality of biological agents therefrom;

one or more sensors adapted to measure one or more performance indicators of said first barrier, the sensors further adapted for inputting the performance indicators to the control unit;

wherein the control unit is adapted to access information for facilitating correlation of the measured performance indicators with a level of removal of the chemical agents and simultaneously a level of removal of the biological agents in the treated water flow.

[0029] The incorporation of a mechanism in the water treatment system for indirectly monitoring the level of removal of a particular chemical or chemical agent by a given barrier allows this barrier to be used simultaneously as a critical control point (CCP) for chemicals as well as biological agent removal in said water treatment system. This has the ability to significantly reduce the costs as well as the risks associated with illness from the presence of both chemical agents and biological agents in water recycling and water production.

[0030] Particular advantages of some embodiments of the present invention include the ability to provide a substantially cheaper route to the production of high performance water substantially free of particular chemicals and biological agents from wastewater or a contaminated water source compared to the prior art. By way of example, the cost savings can be associated with: (a) significantly reduced operational time and costs associated with sampling and transport of regular water samples to a laboratory for analysis, as a risk based approach reduces the need for

frequent sampling; (b) a significant reduction in assays, which are typically expensive as they often involve a wide range of laboratory procedures, highly specialized analytical equipment and the concentrations of chemicals at levels close to the limit of detection; (c) a reduced need for compliance reporting in the form of analytical assays; and/or (d) reduced energy requirements versus other methods of producing high quality water, such as sea water desalination.

[0031] A water treatment system based on the molecular characteristics and mechanism of removal in an individual barrier or combination of barriers (e.g., ozone or ozone plus bacterial activated carbon) has been described previously but has not been incorporated into a critical control point (CCP) approach inclusive of multiple CCP's. Examples include the dosing of ozone to water (inclusive of a range of contaminants), the dosing of peroxide or a similar oxidant into a UV irradiation system, the dosing of a chemical oxidant in a chemical oxidation system, the passage of water through an ion exchange bed, the passage of water through an activated carbon bed or the passage of wastewater through a membrane bioreactor or combined membrane system whereby the probability of removal of a particular chemical is defined by the molecular characteristics of that particular chemical [4-7].

[0032] Suitably, one or more of the barriers described herein, such as the first, second and/or third barriers, are designated as a critical control point in the water treatment system. To define the operational boundaries of a barrier in a water treatment system of the invention, the Critical Control Point (CCP) concept is often used. As used herein, "critical control point" means a function or an area in a water treatment process or procedure, the failure of which, or loss of control over, may have an adverse effect on the performance of the treated water flow and may result in an unacceptable health risk or cause the treated water to have nuisance aesthetic such as poor taste, colour or odour. As such, each CCP typically has one or more specified critical operational limits (e.g., reference or threshold levels) within which they are to function so as to facilitate the appropriate treatment of feed water.

[0033] The CCP approach was first developed by the food and beverage industry as a preventative approach to food safety as distinct from reliance on a final inspection. It focused on the removal of biological, chemical and

physical hazards from food and the approach was used to determine the key points within the manufacturing chain where contamination can be measured and prevented. The same approach was then adopted by water utilities and many water treatment plants now use the CCP approach to construct the operational and management framework of the treatment system. By using the CCP approach, utilities are able to focus resources on monitoring these critical points. These points provide the greatest information and benefit in being able to identify the operational parameters to ensure appropriate water quality, quickly identify and correct any deviations of operating parameters from acceptable limits and significantly reduce the costs of microbial analysis since it is the process and not the final product that is monitored. Along with a quantitative microbial risk assessment (QMRA) to identify the required level of biological agent removal (usually quoted as a log reduction value (LRV)) to mitigate the risk of acute or chronic illness, the CCP approach can be used to design and operate a barrier-oriented water treatment system whereby critical operational limits or threshold levels are typically alarmed within a control unit.

[0034] The basic rules of a CCP approach for the water treatment system of the present invention may include: (a) operational parameters, such as one or more performance indicators of barrier integrity or function, can be measured and critical limits or threshold levels, such as those specific for particular chemical agents and/or biological agents or groups thereof, can be set to define the operational effectiveness of the barrier in question with respect to removal of said chemical agent and/or biological agent (e.g., chlorine residuals for disinfection); (b) operational parameters to be monitored frequently enough (i.e., online and/or continuous/semi-continuous monitoring is preferable) to reveal any failures in a timely manner and raise an alert if required; and (c) procedures for corrective action can be implemented in response to any deviation from these critical limits or threshold levels.

[0035] Further to the above, the difference between small and large communities may also need consideration in the design of a water treatment system of the invention. Accordingly, overall risk assessment in this regard may be incorporated into the water treatment system. In the case of biological agents, it has been demonstrated that the treatment needs of a small community are significantly greater than for a large municipal purified water

recycling plant where pathogens shed by a few people during a disease outbreak are diluted by the bulk flow [8]. Indeed, more stringent pathogen log reduction values (LRV) are required for small communities, between 3 - 6 log higher, to meet a DALY (Disability-Adjusted Life Year) of less than 10^{-6} per person per year [8]. In the case of chemical agents, a similar scenario ensues whereby any chemical spills will be exacerbated in a small community since the buffering capacity of the water treatment system is typically much reduced. As an example, a 100 person community adding 200 litres/day/person to the collection system using a treatment process with a hydraulic residence time of six hours will have an effective volume for dilution of 5,000 litres. In a community of 100,000 people, the same spill would be diluted to 5 ML, a factor of 1,000 different. For chemicals that are added as a result of standard domestic activities, for example, personal care products and pharmaceuticals and their metabolites, there is expected to be little difference between a large municipal and small community water treatment system, save for greater variability as a result of demographic, industrial and societal influences that are not homogenized within the small community.

[0036] Accordingly, it is typically one or more of community size, barrier type, barrier integrity monitoring and risk profile that are used to determine the critical limits or threshold values for each barrier in the water treatment system.

[0037] In the embodiment provided in FIG. 1, the water treatment system 100 includes a plurality of barriers 16, 17, 18, one or more of which are suitable for removing one or more chemicals and/or biological agents from a feed water flow 10. To this end, the barriers 16, 17, 18 may be any known in the art, such as a reverse osmosis unit, an ozonation unit, a UV/peroxide unit, a chemical oxidation unit, an ion exchange bed unit, an activated carbon bed unit, a membrane bioreactor unit, an activated sludge unit, a ceramic or polymeric microfiltration or nanofiltration unit, a chlorination unit, a UV unit, a biologically activated carbon unit, a calcite filter unit or any combination thereof.

[0038] For the embodiment in FIG. 1, the first barrier 110 is adapted to remove both chemical agents and biological agents from the feed water flow 10. To this end, the first barrier may include, for example, a reverse osmosis

unit, an ozonation unit, a UV/peroxide unit, a chemical oxidation unit, an ion exchange bed unit, an activated carbon bed unit, a membrane bioreactor unit, an activated sludge unit or any combination thereof. Conversely, the second barrier 115 is adapted to principally remove: (a) one or more biological agents from the feed water flow 10 with minimal or no removal of chemical agents; or (b) one or more chemical agents from the feed water flow 10 with minimal or no removal of biological agents respectively. In this regard, the second barrier may include, for example, a ceramic or polymeric microfiltration or nanofiltration unit, a chlorination unit, a UV unit, a powdered activated carbon unit or any combination thereof.

[0039] As used herein, the terms “*remove*”, “*removing*”, “*removal*”, “*reduce*”, “*reducing*” or “*reduction*”, as used interchangeably herein, refer to lowering the amount of one or more undesirable components, such as chemical agents and biological agents, in a particular water source. Typically, the removal is barrier-dependent and may occur by, for example, filtration, sterilization, inactivation, absorption, adsorption and degradation, such as cleavage of a molecule into two or more fragments. In light of the above, it would be further appreciated that the term “*remove*” does not imply any particular degree of removal.

[0040] The water treatment system 100 further includes a third barrier 120 which is preferably operable for the alteration of pH, stabilisation of alkalinity and/or the removal of organic matter, solids and/or other impurities from the feed water flow 10. Accordingly, the third barrier 120 is not strictly adapted for the removal of chemical agents and/or biological agents from the feed water flow 10. The third barrier 120 may include, for example, a biologically activated carbon unit, a calcite filter unit or any combination thereof.

[0041] It would be appreciated by the skilled artisan that the first, second and third barriers 110, 115, 120 of the various technologies described herein can be in any order with respect to each other and the flow of water through the water treatment system 100.

[0042] Advantageously, the water treatment system 100 further includes a control unit 110 adapted to monitor and control the operation of the first, second and/or third barriers 110, 115, 120 within the system 100. To this end, the water treatment system 100 has a plurality of sensors 130, 140, 150

associated with the first and second barriers 110, 115 therein. To this end, the sensors 16, 17, 18 may be any known in the art that may be suitable for detecting one or more parameters or indicators with respect to the integrity or functioning of its respective barrier 110, 115.

[0043] More particularly, the first sensor 130 is adapted to measure a first performance indicator 131 of the first barrier 110. To this end, the first performance indicator 131 comprises data with regard to the functioning of the first barrier 110 in respect of its removal of one or more chemical agents and optionally one or more biological agents from the untreated water flow 10 upon its passage therethrough.

[0044] Similarly, the second sensor 140 is adapted to measure a second performance indicator 141 of the first barrier 110. Unlike the first performance parameter 131, the second performance indicator 141 comprises data with regard to the functioning of the first barrier 110 in respect of its removal of biological agents only or chemical agents only.

[0045] It would be appreciated that in particular embodiments, the water treatment system 100 includes only a single sensor, which measures a single performance indicator of the first barrier 110 that may be simultaneously used by the control unit 105 for monitoring the integrity or functioning thereof in respect of the removal of both chemical agents and biological agents.

[0046] By way of example, conductivity may be an appropriate performance indicator of a reverse osmosis unit in terms of the removal of both chemical agents and biological agents. In this regard, conductivity is typically the single most important and most commonly monitored system parameter in a reverse osmosis unit. The conductivity of the feed water is one of the key factors determining reverse osmosis membrane flux and will significantly affect the removal of chemical agents and/or biological agents thereby. Typically, the higher the conductivity, the higher the osmotic pressure, and high osmotic pressure generally makes the RO system less efficient at a given pressure and temperature.

Additionally, in embodiments wherein the first barrier 110 is or comprises an ozonation unit, the performance indicator/s may include one or more of a residual ozone concentration, a ozone dose level, a contact time. Further, in embodiments where the first barrier 110 is or comprises a UV/peroxide unit,

the performance indicator/s may be selected from a UV dose, a peroxide dose, a residual carbon level and any combination thereof. If the first barrier 110 were to comprise a membrane bioreactor unit, then the performance indicator/s may be one or more of a residual turbidity level, a residual carbon level, a nitrogen level, a phosphorus level. In embodiments in which the first barrier 110 is or comprises an activated sludge unit, the performance indicator/s may be selected from a residual turbidity level, a residual carbon level, a nitrogen level, a phosphorus level and any combination thereof. In embodiments in which the first barrier 110 is or comprises an ion exchange bed unit, the performance indicator/s may be selected from a UV absorbance level, a residual turbidity level, a residual carbon level, a fluorescence level and any combination thereof. In embodiments in which the first barrier 110 is or comprises an activated carbon bed unit, the performance indicator/s may be selected from a UV absorbance level, a residual turbidity level, a residual carbon level, a fluorescence level and any combination thereof. In embodiments in which the first barrier 110 is or comprises an chemical oxidation unit, the performance indicator/s may be selected from a solution Eh level, an oxidant dose, a colour level and any combination thereof.

[0047] In those embodiments wherein a single performance indicator is used for indirectly monitoring or estimating the removal of both chemical agents and biological agents from the feed water flow 10, the reference or threshold level may be the same with respect to a chemical agent trigger control point or chemical level monitoring as for a biological agent trigger control point or biological agent level monitoring as performed by the control unit 105. In alternative embodiments, the reference or threshold level of a single performance indicator differs (i.e., is higher or lower) between that required for a chemical agent trigger control point and a biological trigger control point. In one particular embodiment of a barrier that utilises a single performance indicator, the threshold level with respect to a single performance indicator is higher for the determination of a biological agent trigger control point than for that required for a chemical agent trigger control point. In another embodiment of a barrier that utilises a single performance indicator, the threshold level with respect to a single performance indicator is

higher for the determination of a chemical agent trigger control point than for that required for a biological agent trigger control point.

[0048] The control unit 105 of the water treatment system 100 has or otherwise stores a set or database of information with respect to control, reference or threshold levels or values in regards to the first, second and/or third performance indicators 131, 141, 151 that are optimised for producing a treated water flow 20 of a particular quality (e.g., particular acceptable levels of one or more chemical agents and/or biological agents therein). In particular embodiments, this information includes a barrier-specific database of values or levels of relevant performance indicators that have been validated for the removal of particular types of chemicals and/or biological agents, such as those hereinafter provided. Accordingly, the control unit 105 is suitably adapted to utilize the performance indicators 131, 141, 151, such as by correlating or comparing them with a reference value or level in a database, so as to facilitate monitoring or validating a level of removal of the chemical agents and a level of removal of the biological agents in the treated water flow 20.

[0049] It would be appreciated that the particular quality required of the treated water flow 20 may vary between jurisdictions and also certain areas therein, as a result, for example, of differing regulatory requirements and population levels, as noted earlier. Additionally, these threshold levels may be further optimised so as to take into consideration various external factors, such as the particular ambient temperature of the water treatment system 100 and the particular quality of the feed water flow 10 to be treated therein.

[0050] The performance indicators 131, 141, 151 are continuously measured by their respective sensor 130, 140, 150, the values or levels of which are received and monitored by the control unit 105. In this regard, the control unit 105 is capable of autonomously taking mitigating action if any of the levels of the performance indicators 131, 141, 151 received from the sensors 130, 140, 150 indicate that a particular performance indicator 131, 141, 151 is trending towards a threshold level. Typical corrective action may include, for example, cleaning, such as backwashing, sonication and forward flushing, or replacing one or more of the barriers 110, 115, 120. Additionally, a risk assessment with respect to the removal of chemical agents and/or

biological agents may be performed by the control unit 105 in light of this change in function of one or more of the barriers 130, 140, 150.

[0051] If the autonomous corrective actions of the control unit 105 are unsuccessful in mitigating the trend of a performance indicator 131, 141, 151 towards a threshold level or if the above risk assessment requires it, an alert may be generated by the control unit 105 so as to notify a relevant person within the bounds of operating the water treatment system 100. In such a situation, the particular barrier in question or indeed the water treatment system 100 in its entirety may be taken offline for corrective maintenance or re-design.

[0052] The water treatment system 100, and in particular the control unit 105 thereof, may be configured to use any suitable software and/or hardware. From FIG. 1, a control network 107 enables data communication (e.g., communication of performance indicator 131, 141, 151 values) between the sensors 130, 140, 150 of the water treatment system 100 and the control unit 105. Additionally, the control unit 105 may be operably coupled to a data storage unit (not shown), which may include, for example, a system memory, a non-volatile memory, a storage device or the like, as are known in the art. It would be appreciated that the data storage unit may, for example, store data with respect to the threshold levels as well as historical data of the functioning of the respective barriers 130, 140, 150.

[0053] In particular embodiments, the water treatment system 100 comprises a substantially stand-alone platform. If desired, however, the water treatment system 10 may be configured to interact locally or remotely with a broader system, including other resources, servers, entities and even one or more further water treatment systems 100. Such an arrangement allows for the control unit 105 to be easily and regularly reprogrammed as required to accommodate new information, such as new or updated threshold levels with respect to critical limits of one or more of the performance indicators 131, 141, 151.

[0054] FIG. 2 illustrates a method 200 of for operating a water treatment system, such as the water treatment system 100, to produce a treated water flow according to an embodiment of the present invention.

[0055] At step 205, the water treatment system comprising a control unit, a first barrier and one or more sensors is provided. The control unit, first barrier and one or more sensors may include those hereinbefore described.

[0056] At step 210, a feed water flow is passed through a first barrier, which is adapted or configured to remove one or more chemical agents and one or more biological agents therefrom. In particular embodiments, the first barrier is selected from the group consisting of a reverse osmosis unit, an ozonation unit, a UV/peroxide unit, a chemical oxidation unit, an ion exchange bed unit, an activated carbon bed unit, a membrane bioreactor unit, an activated sludge unit and any combination thereof.

[0057] At step 215, the one or more sensors measures one or a plurality of performance indicators regarding the functioning and/or integrity of the first barrier. By way of example, if the first barrier were a reverse osmosis unit then the one or plurality of performance indicators may include a level of membrane conductivity and a pressure decay test level, a residual carbon level, a sulphate level or any combination thereof. In particular embodiments, the pressure decay test level is performed as a batch measurement using a pressure transducer.

[0058] At step 220, the control unit receives the one or more measured performance indicators. In particular embodiments, the control unit is configured to receive the one or more measured indicators at pre-determined intervals. Alternatively, the control unit may be configured to receive a continuous feed or input thereof.

[0059] At step 225, the control unit processes the one or more measured performance indicators to calculate or estimate a level of removal of the chemical agents and the biological agents. The control unit thus correlates the performance indicator with a level of removal of one or a plurality of chemical agents and a level of removal of one or a plurality of biological agents. The control unit may further identify any changes in function of the first barrier so as to generate a trigger control point with respect to said change. If required, the control unit may further determine the provisioning of an alarm, such as a visual and/or audible notification, if the performance indicators fall below or rise above a specified reference or threshold level.

EXAMPLES

EXAMPLE 1

[0060] The enhanced pathogen reduction requirements associated with a small community using a seven barrier treatment process inclusive of ozonation, ceramic micro-filtration (MF), biologically activated carbon (BAC), reverse osmosis (RO), UV treatment, calcite filtration and chlorination (Cl_2) is shown in Table 1. The pathogen LRV and required performance indicator for each barrier is shown in Table 1, from which the operational critical limits or threshold values are then specified for each performance indicator.

[0061] **Table 1:** Claimed LRVs for a seven barrier treatment system and CCP sensor type for each barrier.

Barrier	CCP	LRV*		
		Virus	Bacteria	Protozoa
Ozonation	CT	2	2	0
Ceramic MF	PDT	1	1	4
BAC	Turbidity	0	0	0
RO	Conductivity and PDT	1.5	1.5	2
UV	Measured dose	4	4	4
Calcite Filter	pH	0	0	0
Chlorination	CT	4	4	0
Total claimed LRVs		12.5	12.5	10

* The LRVs are credited based on the USEPA Long Term 2 Enhanced Surface Water Treatment Rule. CT = contact time, PDT = pressure decay test.

[0062] In the case of chemical agents, a similar table can be generated based on molecular characteristics for an ozone barrier and a reverse

osmosis barrier using a sub-set of the above threshold value requirements for biological agents. It should be noted that greater operational requirements may be necessary for chemical agent removal than in the case of biological agents (or vice versa), and although this would not alter the claimed LRV in Table 1 for biological agents, the water treatment system would be required to adopt the more rigorous critical limits or threshold values.

[0063] Additionally, different performance indicators may need to be monitored or considered for a given barrier. For example, whereas conductivity may be considered a suitable performance indicator of membrane integrity for a reverse osmosis barrier in the case of chemical agents, a pressure decay test (PDT), which is a performance indicator of the integrity of such a barrier to particles of diameter greater than 3 microns, may not necessarily be suitable for particular chemical agents.

[0064] The molecular characteristics of the chemical agents to be removed may be based on their chemical groupings and sub-groupings relating to their removal by the particular barrier treatment process/es, as shown in Table 2. The probability of removal of the chemical groups/subgroups provided in Table 2 by an ozone barrier operating under similar contact time conditions as for the biological agents in Table 1 (is shown in Tables 2 and 3.

Table 2: Molecular groupings and sub-groupings for an ozone barrier

Major Groupings	Sub-groupings	Designation
Aromatic	Compounds with electron withdrawing groups (EWG) including nitrosamine, halogens, ethynyl, carboxyl, ester, amide	Aromatic EWG
	Compounds with electron donating groups (EDG) and electron rich rings including acyl, amino, hydroxyl, alkoxy, alkyl	Aromatic EDG
	Compounds with combinations of EWG	Aromatic other

	and EDG (other)	
Aliphatic	Compounds with double bonds and EDG	Aliphatic EWG
	Compounds with EWG	Aliphatic EDG
	Compounds with combinations of EWG and EDG	Aliphatic other
Inorganic	Metals including Pb, Cd, Fe and Hg	Inorganic metals
	Inorganics N containing compounds	Inorganic N
	Radiological	Inorganic Radiological
	Other	Inorganic other

Table 3: Claimed LRVs for chemical agents of an ozone barrier using residual ozone concentration (0.05 mg/L) multiplied by contact time (CT=5 minutes) to give a critical limit or threshold value of 0.25 mg.min/L as a surrogate or indirect indicator of performance.

Group	Sub-Group	LRV
Aromatic	EWG	0
	EDG	1
	Other	0
Aliphatic	EWG	0
	EDG	1
	Other	0
Inorganic	All sub-groups	0

[0065] A similar process based on the major chemical groupings but using the molecular characteristics of molecular weight, charge and hydrophobicity for a reverse osmosis (RO) barrier using the conductivity threshold levels used for the biological agents in Table 1, is shown in Tables 4 and 5.

Table 4: Molecular groupings and sub-groupings for an RO barrier

Major Groupings	Sub-groupings	Designation
Organic	Charged	Organic Charged
	Neutral, MW<400	Organic Neutral Low
	Neutral, MW>400	Organic Neutral High
Inorganic	Metals including Pb, Cd, Fe and Hg	Inorganic Metals
	Inorganics N containing compounds	Inorganic N
	Radiological	Inorganic Radiological
	Other (uncharged)	Inorganic uncharged
	Other	Inorganic other

Table 5: Claimed LRVs for chemical agents of a reverse osmosis barrier using conductivity with a critical limit LRV>1.5 as a surrogate of performance.

Group	Sub-Group	LRV
Organic	Charged	1
	Neutral Low	0.5
	Neutral High	1
Inorganic	Metals	1.5
	N	1
	Radiological	1.5
	Inorganic other	1.5
	Inorganic uncharged	0

[0066] Choosing a test molecule as an example, Table 1 can be reconstructed for some example chemical agents, ibuprofen and triclosan, using the combined designations of Tables 3 and 5. The designation of the two chemicals is shown in Table 6. Further barriers may be included, such as a membrane bioreactor and other oxidative barriers, for enhanced removal of these or further chemical agents.

Table 6: Example of molecular classification based on decision tree analysis

Chemical	Ozone Designation	RO Designation	Characteristics
Ibuprofen	Aromatic EDG	Organic Charged	MW=206.281, K _{ow} =2.23, pKa=5.2
Triclosan	Aromatic EWG	Organic Charged	MW=289.5, K _{ow} =4.76, pKa=7.9

Table 7: Claimed LRVs for a seven barrier treatment system and CCPs for each barrier.

Barrier	CCP	LRV Ibuprofen	LRV Triclosan
Ozonation	CT	1	0
Ceramic MF	PDT	0	0
BAC	Turbidity	0	0
RO	Conductivity and PDT	1	1
UV	Measured dose	0	0
Calcite Filter	pH	0	0
Chlorination	CT	0	0
Total claimed LRVs		2	1

[0067] In addition to the ozone and reverse osmosis units exemplified above, other barriers that may be suitable for monitoring by sensors with respect to estimating both chemical agent and pathogen removal (i.e., a joint performance indicator for pathogen removal and chemical removal) from a feed water flow include a UV/peroxide unit, a chemical oxidation unit, an ion exchange bed unit, an activated carbon bed unit, an MBR or an activated sludge unit. In this case, the particular chemicals or groups thereof removed may be based, at least in part, on the hydrophobicity of the molecule.

[0068] Although many of the barriers do not represent a CCP barrier for chemical agents, the water treatment system allows a simultaneous CCP hierarchy of trigger control points for any chemical.

EXAMPLE 2

[0069] Below is provided an example of an ozonation unit operated at Selfs Point Wastewater Treatment Plant in Tasmania, which is suitable for use in the water treatment system of the present invention. A schematic diagram of the plant is provided in Figure 3.

Ozonation Unit Design and Specifications

[0070] Supplier – Wedeco, OCS-GSO 10; Maximum ozone production = 30 g/h; continuous with internal recycle; HRT₁₀ = HRT when 10% of the flow has exited the ozone system (flowrate = 20 L/min) = 4.8 min (4.8 and 5.2 min measured for HRT₁₀ using Rhodamine WT).

Removal Mechanisms

[0071] Biological agents are inactivated by oxidation with ozone.

Reported LRV for Ozone

[0072] US EPA Long Term 2 Enhanced surface water treatment rule toolbox guidance manual, April 2010 (<http://www.epa.gov/safewater>) Chapter 11, Table 11.1 outlines the required CT values for *Cryptosporidium* inactivation from surface waters and these values were determined using reagent grade water. The required CT value = 2.0 at 20°C for a *Cryptosporidium* LRV of 0.5. For virus, the US EPA Guidance Manual

Disinfection Profiling and Benchmarking , The CT value = 0.5 for a virus LRV of 4 at 20°C, and 0.25 for a virus LRV of 2 at 20°C.

[0073] To validate the ozone system at Selfs Point according to the Draft Ozone Validation Guidelines was problematic because of the non-particle free nature of this water and the resources required to validate the process according to these guidelines. Currently, all monitoring of the ozone system at Selfs Point has demonstrated >2 LRV for native *E. coli* when either there were no *E. coli* left in the treated water or the feedwater concentration was characterised as being >2,419, and > 2.7 LRV when a LRV could be calculated (see Table 8 and Figure 4). This was true even when the feedwater deteriorated badly (turbidity >5 NTU, ammonia >6 mg/L) during a scheduled settler maintenance period. LRV of >4 for *E. coli* was reported for periods of low ozone residual. LRV >2 for virus has also been observed at Selfs Point even when there was no residual ozone (Table 2). Future operations will target ozone residuals equivalent to those required for 4 LRV virus by the USA EPA CT values, but in the event these cannot be reached, the ozone dose will remain high (11.7-14 mg/L and 1.3-1.7 mg O₃/ mg DOC). This is the mode of operation at Selfs Point that has been demonstrated to achieve LRV >2.

[0074] Monitoring data from Selfs Point from 17/9/2014 to 27/5/2015 are shown in Table 8.

Table 8. Microbial concentrations and LRV for ozonation

Date	<i>E. coli</i>			Somatic Coliphage			Residual Ozone (mg/L)
	Feed (MPN/100mL)	Post ozone (MPN/100 mL)	LRV	Feed (pfu/100 mL)	Post ozone (pfu/100mL)	LRV	
17/9/14	1986.3	3.1	2.81				0.47
24/9/14	1553.1	4.1	2.58				0.21
1/10/14	1732.9	5.2	2.52				0.39
8/10/14	1553.1	4.1	2.58				0.48
15/10/14	>2419.6	2.0	3.08				0.30
22/10/14	>2419.6	4.1	>2.77				0.16
29/10/14	>2419.6	1.0	>3.38				0.87
5/11/14	>2419.6	3.1	>2.89				0.23
12/11/14	>2419.6	4.1	>2.77				0.28
19/11/14	>2419.6	1.0	>3.38				0.04
26/11/14*	13500	1.0	4.13				0.00
2/12/14	24300	2.0	4.08				0.01
10/12/14	290900	4.1	4.85				0.04
17/12/14	285100	39.9	3.85	834	<1	>2.92	0.00
21/1/15	770100	24.3	4.50				0.00
28/1/15	90900	12.2	3.87				0.02
28/1/15	53300	7.5	3.85				0.00
4/2/15	62000	9.7	3.81				0.00
4/2/15	18700	12	3.19				0.01
11/2/15	>2419.6	21.6	>2.05				0.00
11/2/15	>2419.6	12.1	>2.30				0.00
18/2/15	150000	72.3	3.31				0.00
18/2/15	108100	37.9	3.46				0.00
25/2/15	25300	3	3.93	3000	1	3.48	0.00
25/2/15	27500	15.8	3.24				0.03
4/3/15	28200	6.3	3.65				0.00
4/3/15	28100	55.4	2.71				0.00
11/3/15	74300	24.6	3.48				0.00
11/3/15	70600	14.6	3.68				0.00
25/03/15	39300	2	4.29	12000	7	3.23	0.14
25/03/15	48700	10.8	3.65				0.12
1/04/15	8600	4.1	3.32				0.00
1/04/15	9700	18.9	2.71				0.10
15/04/15	14800	2	3.87				0.10
15/04/15	5200	1	3.72				0.05
22/04/15	3100	7.5	2.62	4200	5	2.92	0.16
22/04/15	5200	1	3.72				0.05
29/04/15	9700	7.3	3.12				0.19
29/04/15	7500	8.7	2.94				0.15
6/05/15	16100	3	3.73	2500	<1	>3.40	0.46
6/05/15	14600	3.1	3.67				0.63
20/05/15	128650	27.5	3.67				0.10
20/05/15	133300	23.3	3.76				0.42
27/05/15	178500	7.4	4.38				0.36
27/05/15	222400	5.2	4.63				0.39

[0075] Note: For this system, the US EPA CT values (@19°C) require a residual of 0.35 mg/L ozone for 0.5 LRV protozoa, 0.1 mg/L for 4 LRV virus and bacteria and 0.05 mg/L for 2 LRV virus and bacteria.

Required Operating Parameters

[0076] Flowrate < 20±10% L/min (T_{10} = 4.8 min) and Residual concentration >0.05 for LRV =2 (virus) (claimed LRV); or

[0077] Flowrate < 20±10% L/min (T_{10} = 4.8 min) and ozone dose > 11.7 mg/L and >1.3 mg O_3 / mg DOC.

EXAMPLE 3

[0078] Below is provided an example of a reverse osmosis unit operated at Selfs Point Wastewater Treatment Plant in Tasmania, which is suitable for use in the water treatment system of the present invention.

RO Design and Specifications

[0079] Membranes- Dow BW30

[0080] Module design – 5 x single elements in series

[0081] Mode of operation – operated at 70% recovery with recirculation to achieve this, semi-continuous with near continuous operation in the summer and operation for 4 hours every second day during winter, membranes are flushed with permeate whenever they shut down. An osmotic backwash has been observed when shut down.

[0082] Average Flux – 23 L/m².h

[0083] Monitoring permeate - conductivity, flowrate

[0084] On-line integrity sensors – conductivity across each element and across the feed and permeate, pressure decay test for protozoa and helminths

Removal Mechanisms

[0085] Size exclusion for all biological agents.

Reported LRV for RO

[0086] It is generally understood that RO can achieve very high LRVs for all biological agents but may be compromised by faulty o-rings or defects in the membrane. Therefore, on-line monitoring is required and the limitations of the on-line verification usually limit the approved LRV values, with LRV of 1.5-2 being usual.

[0087] This system uses conductivity across the process for on-line verification. An LRV of 1.5 can be claimed for biological agents based on conductivity across the RO system (see, e.g., Figure 5).

Required Operating Parameters

[0088] Conductivity is a conservative surrogate for pathogen removal across reverse osmosis membranes, as the conductivity reduction is always lower than the pathogen reduction. Hence, operating parameters have no effect on the use of conductivity for LRV calculations, and there is no requirement to control the operating parameters of the RO system to a region where LRV measured by conductivity is valid. Data confirming this is contained in the Australian Water Recycle Centre of Excellence NatVal project reports on RO validation and in the Water Reuse Research Foundation project reports (WateReuse-12-07).

[0089] All computer programs, algorithms, patent and scientific literature referred to herein is incorporated herein by reference.

[0090] The above description of various embodiments of the present invention is provided for purposes of description to one of ordinary skill in the related art. It is not intended to be exhaustive or to limit the invention to a single disclosed embodiment. As mentioned above, numerous alternatives and variations to the present invention will be apparent to those skilled in the art of the above teaching. Accordingly, while some alternative embodiments have been discussed specifically, other embodiments will be apparent or relatively easily developed by those of ordinary skill in the art. The invention is intended to embrace all alternatives, modifications, and variations of the present invention that have been discussed herein, and other embodiments that fall within the spirit and scope of the above described invention.

REFERENCES

1. Brown, R.A. *Application of the Long Term 2 Enhanced Surface Water Treatment Rule Microbial Toolbox at Existing Water Plants*. 2003. Fountain Valley Calif, National Water Research Institute.
2. EPHC, NHMRC, and NRMCC *Australian Guidelines for Water Recycling: Managing health and environmental risks (Phase 2). Augmentation of drinking water supplies*. 2008.
3. NHMRC and NRMCC *Australian Drinking Water Guidelines Paper 6, National Water Quality Management Strategy*. 2011.
4. Dickenson, E.R., et al., *Applying surrogates and indicators to assess removal efficiency of trace organic chemicals during chemical oxidation of wastewaters*. Environmental Science & Technology, 2009. **43**: p. 6242-6247.
5. Dickenson, E.R.V., et al., *Indicator compounds for assessment of wastewater effluent contributions to flow and water quality*. Water Research, 2011. **45**: p. 1199-1212.
6. Tadkaew, N., et al., *Removal of trace organics by MBR treatment: The role of molecular properties*. Water Research, 2011. **45**: p. 2439-2451.
7. Alturki, A.A., et al., *Combining MBR and NF/RO membrane filtration for the removal of trace organics in indirect potable water reuse applications*. Journal of Membrane Science, 2010. **365**: p. 206-215.
8. Barker, S.F., et al., *Pathogen reduction requirements for direct potable reuse in Antarctica: Evaluating human health risks in small communities*. Science of the Total Environment, 2013. **461**: p. 723-733.
9. US EPA Long term 2 Enhanced Surface Water Treatment Rule Toolbox Guidance Manual, April 2010 http://www.epa.gov/safewater/disinfection/lt2/pdfs/guide_lt2_toolboxguidance_manual.pdf.
10. US EPA Guidance Manual Disinfection Profiling and Benchmarking, August 1999, <http://www.epa.gov/ogwdw000/mdbp/pdf/profile/benchpt1.pdf>
11. US EPA Effect of particulates on ozone disinfection of bacteria and virus in water, August 1979.

12 Mieog and McNeil, Recycled water treatment on a large scale using multiple disinfection barriers at Melbourne Water's Eastern Treatment Plant. AWA Water Recycling conference, Brisbane, 2-3 July, 2013.

13. Department of Health, Victoria, Guidelines for validating treatment processes for pathogen reduction, Supporting Class A recycled water schemes in Victoria, Feb. 2013.

CLAIMS

1. A water treatment system for producing a treated water flow comprising;

a control unit;

a first barrier for receiving a feed water flow therethrough and operable to remove one or a plurality of chemical agents and one or a plurality of biological agents therefrom; and

one or more sensors adapted to measure one or more performance indicators of said first barrier, the sensors further adapted for inputting the performance indicators to the control unit;

wherein the control unit is adapted to access information for facilitating correlation of the measured performance indicators with a level of removal of the chemical agents and simultaneously a level of removal of the biological agents.

2. The system of Claim 1, comprising a first sensor adapted to measure a first performance indicator of said first barrier, wherein the control unit is adapted to correlate the first performance indicator with the level of removal of the chemical agents and the level of removal of the biological agents.

3. The system of Claim 1, comprising:

a first sensor adapted to measure a first performance indicator of said first barrier; and

a second sensor adapted to measure a second performance indicator of said first barrier;

wherein the control unit is adapted to correlate: (i) the first performance indicator with the level of removal of the chemical agents; and (ii) the second performance indicator with the level of removal of the biological agents.

4. The system of any one of the preceding claims, wherein the first barrier is selected from the group consisting of a reverse osmosis unit, an ozonation unit, a UV/peroxide unit, a chemical oxidation unit, an ion exchange bed unit, an activated carbon bed unit, a membrane bioreactor unit, an activated sludge unit and any combination thereof.

5. The system of Claim 4, wherein the first barrier is or comprises:

(i) the reverse osmosis unit and the performance indicators are selected from the group consisting of a level of membrane conductivity, a pressure decay test level, a residual carbon level, a sulphate level and any combination thereof;

(ii) the ozonation unit and the performance indicators are selected from the group consisting of a residual ozone concentration, a ozone dose level, a contact time and any combination thereof ;

(iii) the UV/peroxide unit and the performance indicators are selected from the group consisting of a UV dose, a peroxide dose, a residual carbon level and any combination thereof;

(iv) the membrane bioreactor unit and the performance indicators are selected from the group consisting of a residual turbidity level, a carbon level, a nitrogen level, a phosphorus level and any combination thereof;

(v) the activated sludge unit and the performance indicators are selected from the group consisting of a residual turbidity level, a carbon level, a nitrogen level, a phosphorus level and any combination thereof;

(vi) the chemical oxidation unit and the performance indicators are selected from the group consisting of a solution Eh level, an oxidant dose, a colour level and any combination thereof;

(vii) the ion exchange unit and the performance indicators are selected from the group consisting of a UV absorbance level, a residual turbidity level, a residual carbon level, a fluorescence level and any combination thereof;

and/or

(vi) the activated carbon bed unit and the performance indicators are selected from the group consisting of a UV absorbance level, a residual turbidity level, a residual carbon level, a fluorescence level and any combination thereof.

6. The system of any one of the preceding claims, further comprising a second barrier for receiving the untreated water flow therethrough and operable to remove either one or a plurality of biological agents therefrom or alternatively, one or a plurality of chemical agents therefrom.

7. The system of Claim 6, further comprising a third sensor adapted to measure a third performance indicator of the second barrier, the third sensor further adapted for inputting the third performance indicator to the control unit, wherein the control unit is adapted to correlate the third performance indicator with the level of removal of either the biological agents or chemical agents.

8. The system of Claim 6 or Claim 7, wherein the second barrier is selected from the group consisting of a microfiltration unit, a nanofiltration unit, a chlorination unit, a powdered activated carbon unit, a UV unit and any combination thereof.

9. The system of any one of the preceding claims, further comprising a third barrier selected from the group consisting of a biologically activated carbon unit, a calcite filter unit and any combination thereof.

10. The system of any one of the preceding claims, wherein the sensors provide real-time and/or at least semi-continuous measurement of the performance indicators to the control unit.

11. The system of any one of the preceding claims, wherein the control unit is further adapted to compare the performance indicators with a threshold level to identify a change in function of the first barrier and/or the second barrier and generate a trigger control point in accordance with the change.

12. The system of Claim 11, wherein the control unit generates an alert if the performance indicators are above or below the threshold level.

13. The system of Claim 11 or Claim 12, wherein the threshold level is determined at least in part by a molecular characteristic of the one or plurality of chemical agents or the microbial characteristics of the one or plurality of biological agents.

14. The system of any one of the preceding claims, wherein the first, second and/or third barriers are designated as a critical control point in the water treatment system.

15. A method for operating a water treatment system to produce a treated water flow, including the steps of:

providing the water treatment system comprising a control unit, a first barrier and one or more sensors;

passing a feed water flow through the barrier to remove one or a plurality of chemical agents and one or a plurality of biological agents therefrom;

measuring one or more performance indicators of the barrier by the one or more sensors;

inputting the one or more performance indicators measured by the sensors into the control unit; and,

correlating the one or more performance indicators by the control unit with a level of removal of the one or plurality of chemical agents and a level of removal of the one or plurality of biological agents.

16. The method of Claim 15, wherein the water control system comprises a first sensor adapted to measure a first performance indicator of said first barrier, wherein the control unit correlates the first performance indicator with the level of removal of the chemical agents and the level of removal of the biological agents in the treated water flow.

17. The method of Claim 15, wherein the water control system comprises a first sensor adapted to measure a first performance indicator of said first barrier; and a second sensor adapted to measure a second performance indicator of said first barrier, wherein the control unit correlates: (i) the first performance indicator with the level of removal of the chemical agents; and (ii) the second performance indicator with the level of removal of the biological agents.

18. The method of Claim 16 or Claim 17, wherein the first barrier is selected from the group consisting of a reverse osmosis unit, an ozonation unit, a UV/peroxide unit, a chemical oxidation unit, an ion exchange bed unit, an activated carbon bed unit, a membrane bioreactor unit, an activated sludge unit and any combination thereof.

19. The method of Claim 18, wherein the first barrier is or comprises:

(i) the reverse osmosis unit and the performance indicators are selected from the group consisting of a level of membrane conductivity, a pressure decay test level, a residual carbon level, a sulphate level and any combination thereof;

(ii) the ozonation unit and the performance indicators are selected from the group consisting of a residual ozone concentration, a ozone dose level, a contact time and any combination thereof ;

(iii) the UV/peroxide unit and the performance indicators are selected from the group consisting of a UV dose, a peroxide dose, a residual carbon level and any combination thereof;

(iv) the membrane bioreactor unit and the performance indicators are selected from the group consisting of a residual turbidity level, a carbon level, a nitrogen level, a phosphorus level and any combination thereof;

(v) the activated sludge unit and the performance indicators are selected from the group consisting of a residual turbidity level, a carbon level, a nitrogen level, a phosphorus level and any combination thereof.

(vi) the chemical oxidation unit and the performance indicators are selected from the group consisting of a solution Eh level, an oxidant dose, a colour level and any combination thereof;

(vii) the ion exchange unit and the performance indicators are selected from the group consisting of a UV absorbance level, a residual turbidity level, a residual carbon level, a fluorescence level and any combination thereof;

and/or

(vi) the activated carbon bed unit and the performance indicators are selected from the group consisting of a UV absorbance level, a residual turbidity level, a residual carbon level, a fluorescence level and any combination thereof.

20. The method of any one of Claims 15 to 19, wherein the step of measuring the one or more performance indicators is performed by the sensors in a real-time and/or at least semi-continuous manner.

21. The method of any one of Claims 15 to 19, further including the step of comparing the performance indicators with a threshold level by the control unit to identify a change in function of the barrier.

22. The method of Claim 21, further including the step of generating a trigger control point in accordance with the change in function of the barrier.

23. The method of Claim 21 or 22, wherein the control unit generates an alert if the performance indicators are above or below the threshold level.

24. The method of any one of Claims 21 to 23, wherein the threshold level is determined at least in part by a molecular characteristic of the one or plurality of chemical agents and/or a microbial characteristic of the one or plurality of biological agents.

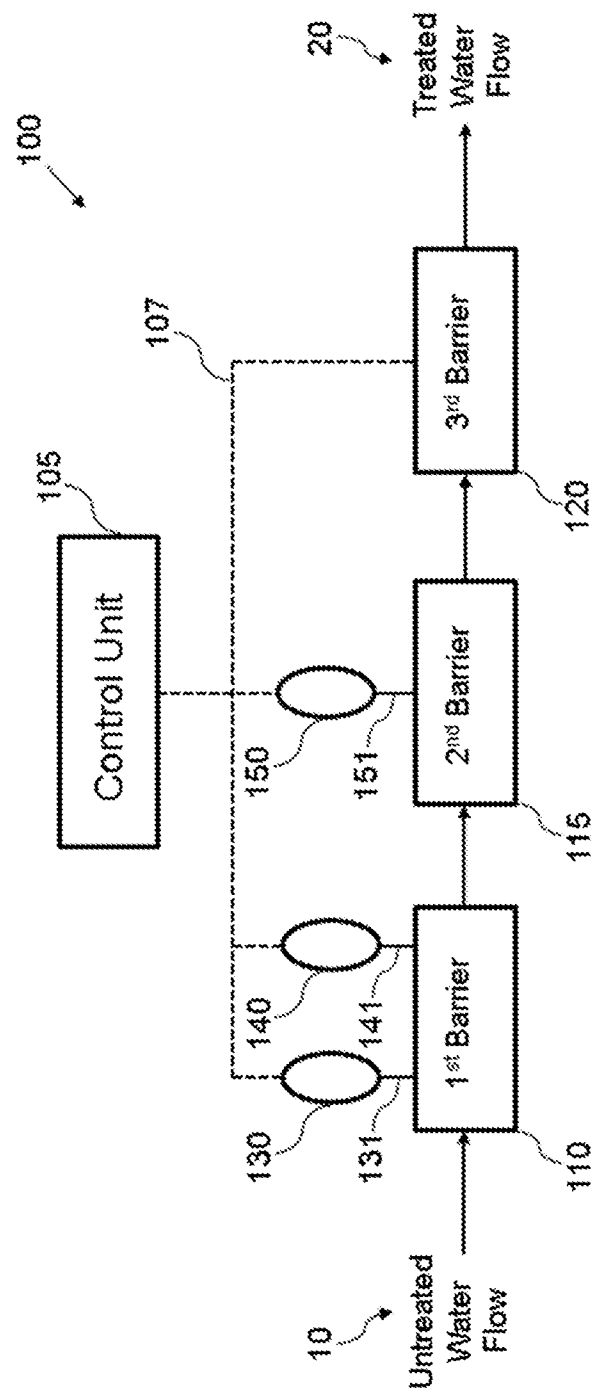
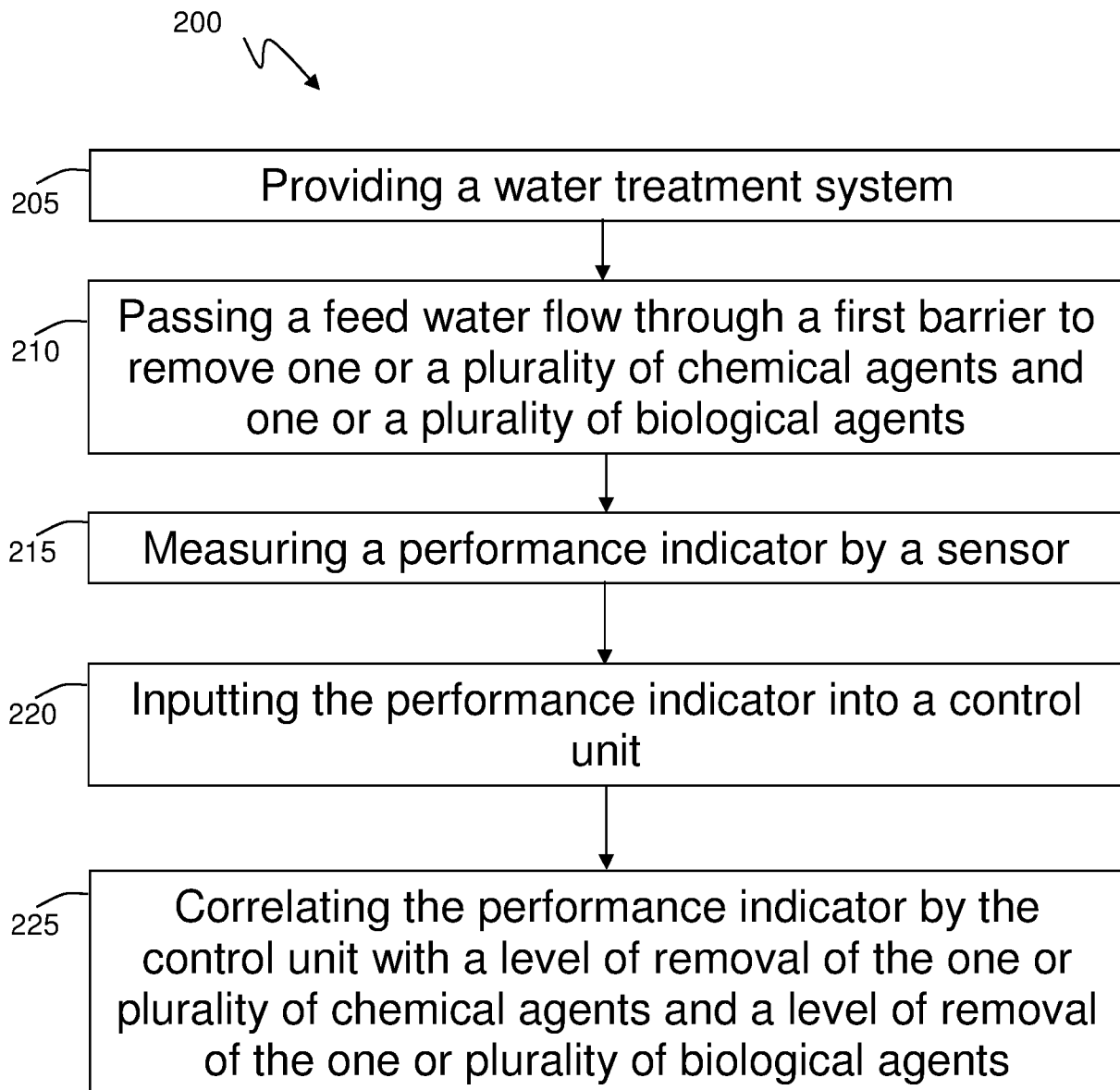


FIG. 1

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**FIG. 2**

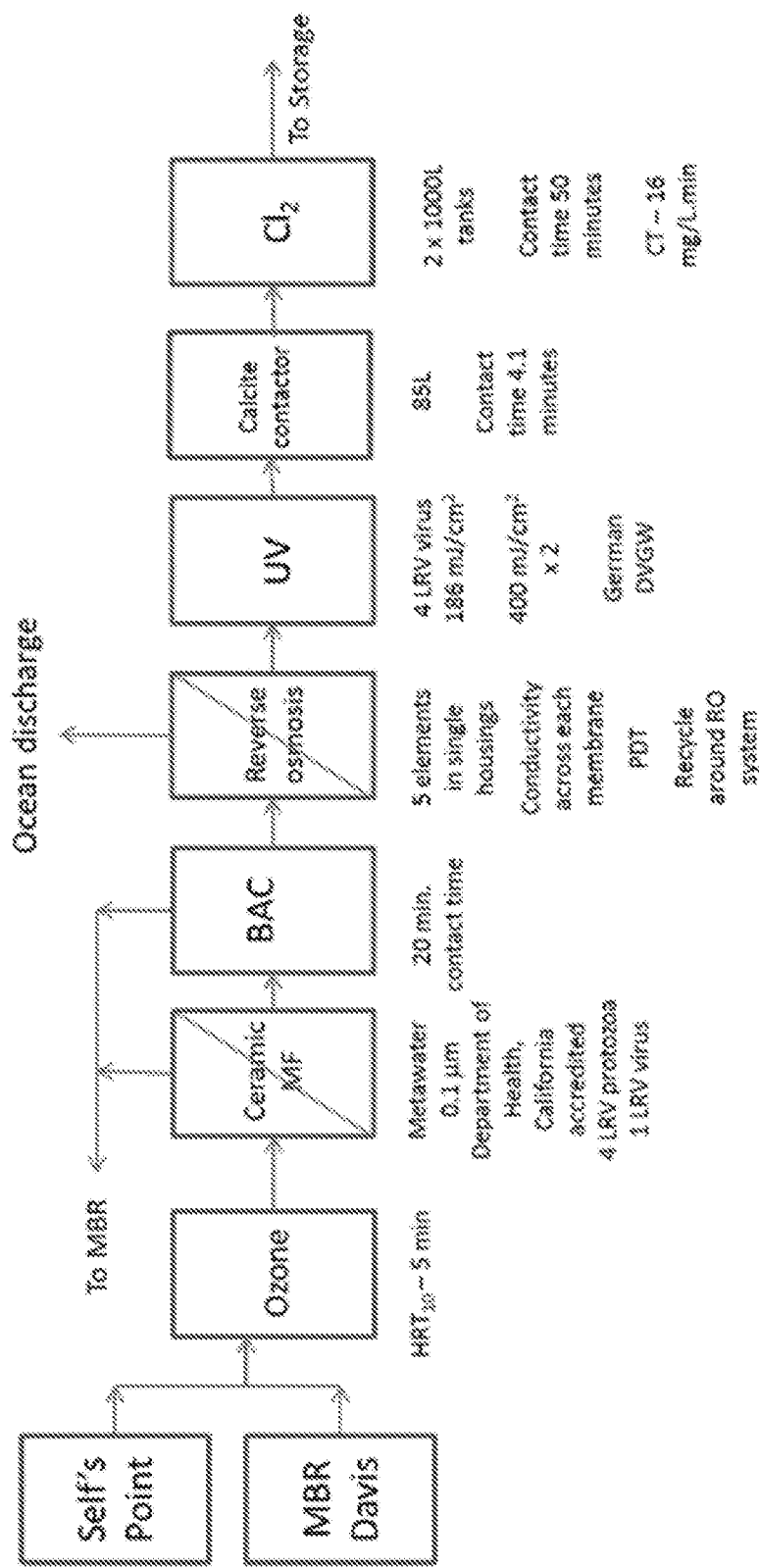


FIG. 3

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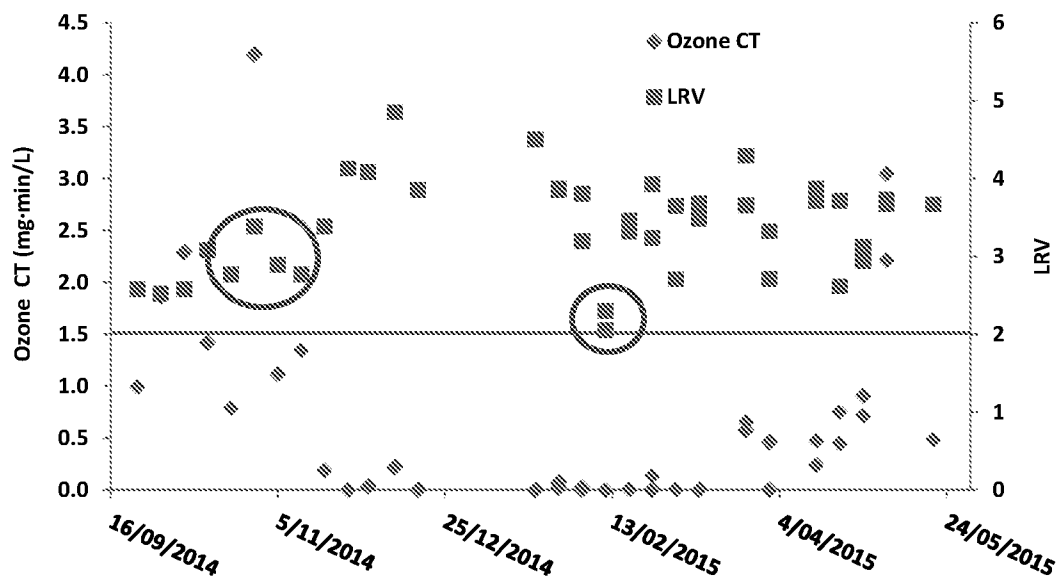
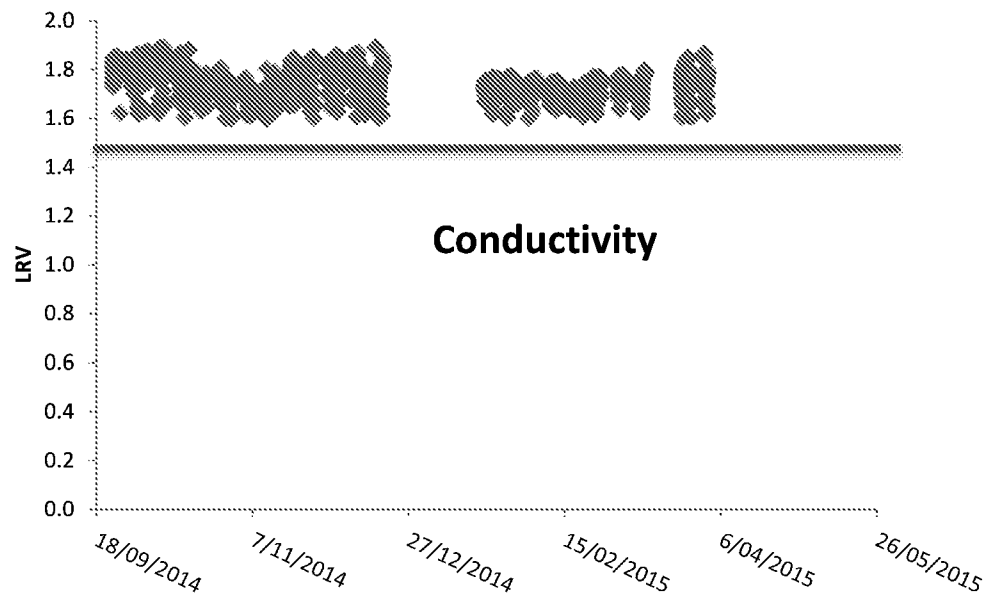


FIG. 4

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**FIG. 5**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2017/050899

A. CLASSIFICATION OF SUBJECT MATTER

C02F 9/04 (2006.01) C02F 1/78 (2006.01) C02F 1/32 (2006.01) C02F 1/44 (2006.01) C02F 101/30 (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)

Database : EPODOC, WPIAP, TXPEA, TXPEB, TXPEC, TXPEE, TXPEF, TXPEH, TXPEI, TXPEP, TXTPEPEA, TXTEPEB, TXPES, TXPEU, TXPEY, TXPUSE0A, TXPUSE1A, TXPUSEA, TXPUSEB, TXPW0EA; IPC and CPC: C02F2209/00/LOW, C02F2101/30, C02F2303/04, C02F9/00/LOW, C02F1/008, C02F1/32, C02F1/44, C02F1/72, C02F1/78, C02F3/12, C02F101/30, G05B13/0275, G05B13/02 using keywords such as: vessel, water, treatment, chemical, agent, pathogen, ozone, membrane, UV, sensor, control and their similar keywords. AusPat, Google Patents, Espacenet Science Direct, and Google Scholar were searched using keywords such as vessel, water, treatment, chemical, agent, pathogen, ozone, membrane, UV, sensor, control and their similar keywords. AusPat, USPTO, Espacenet and in internal databases provided by IP Australia were searched for applicant/inventors.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	



Further documents are listed in the continuation of Box C



See patent family annex

* "A"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance	"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
"E"	earlier application or patent but published on or after the international filing date	"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
"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)	"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
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search
28 November 2017Date of mailing of the international search report
28 November 2017

Name and mailing address of the ISA/AU

AUSTRALIAN PATENT OFFICE
PO BOX 200, WODEN ACT 2606, AUSTRALIA
Email address: pct@ipaustalia.gov.au

Authorised officer

Abdulla Al-Motin
AUSTRALIAN PATENT OFFICE
(ISO 9001 Quality Certified Service)
Telephone No. 0262837965

INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		PCT/AU2017/050899
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014/152176 A2 (OMNI WATER SOLUTIONS, INC.) 25 September 2014 (Abstract, paragraphs [0002, 0011-0012, 0014,0019, 0021, 0049-0051, 0057,0075, 0083, 0090, 0096-0097, 00108-00109, 00115, 00161]; claims 1-13; figures 1-3, 7-8)	1-24
X	US 9150432 B2 (CASTILLO RIVERA et al.) 06 October 2015 (Abstract; column 3, line 29 – 48; column 4, lines 15-22; column 4, line 63- column 5, line 5; column 5, lines 63-67; column 6, lines 28-34; claims 1-5 and figure 1)	1-6, 8 and 16-20
P,X	US 2016/0280562 A1 (RAYVIO CORPORATION) 29 September 2016 (Abstract, figures 1-5; claims 1-10; paragraphs [0007, 0009-0010, 0023, 0031, 0041 and 0053])	1-6, 8-10 and 15-20
P,X	US 2017/0088436 A1 (VERTAQUA LLC) 30 March 2017 (Abstract, figures 1 and 3, paragraphs [0006, 0008, 0022-0023, 0030], claim 1)	1- 6 and 15-19

Form PCT/ISA/210 (fifth sheet) (July 2009)

INTERNATIONAL SEARCH REPORT		International application No.	
Information on patent family members		PCT/AU2017/050899	
This Annex lists known 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/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
WO 2014/152176 A2	25 September 2014	WO 2014152176 A2	25 Sep 2014
		CA 2760807 A1	18 Nov 2010
		EP 2467336 A1	27 Jun 2012
		JP 2012526657 A	01 Nov 2012
		JP 5726176 B2	27 May 2015
		MX 2011011660 A	18 Nov 2011
		US 2010292844 A1	18 Nov 2010
		US 8486275 B2	16 Jul 2013
		US 2013313191 A1	28 Nov 2013
		WO 2010132859 A1	18 Nov 2010
US 9150432 B2	06 October 2015	US 2011259832 A1	27 Oct 2011
		US 9150432 B2	06 Oct 2015
		AU 2009275991 A1	04 Feb 2010
		CA 2728754 A1	04 Feb 2010
		EP 2307319 A1	13 Apr 2011
		EP 2307319 B1	07 Nov 2012
		FR 2934586 A1	05 Feb 2010
		FR 2934586 B1	27 Aug 2010
		WO 2010012693 A1	04 Feb 2010
US 2016/0280562 A1	29 September 2016	US 2016280562 A1	29 Sep 2016
		CN 106020133 A	12 Oct 2016
		US 2016278424 A1	29 Sep 2016
		US 2016289090 A1	06 Oct 2016
		US 2017190598 A1	06 Jul 2017
		US 2017280737 A1	05 Oct 2017
US 2017/0088436 A1	30 March 2017	US 2017088436 A1	30 Mar 2017
End of Annex			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.			