

DISINFECTION DEVICE AND MODULE FOR DISINFECTING FLUIDS

TECHNICAL FIELD

5 [0001] The present disclosure relates to a disinfection module and/or a disinfection device suitable for disinfecting fluids.

BACKGROUND

10 [0002] The following discussion of the background is intended to facilitate understanding of the present disclosure. However, it should be appreciated that the discussion is not an acknowledgment or admission that any of the material referred to was published, known or a part of the common general knowledge in any jurisdiction as at the priority date of the application.

15 [0003] Due to the spread of highly contagious diseases, there exists an increased need for disinfection and/or sterilization of facilities, in particular facilities involving the flow of fluid. Non-limiting examples of such fluids include the culture fluid of hydroponics system, chlorinated water in swimming pools, recycled water from treatment systems, sterilized air in enclosed areas, and the like.

20 [0004] In particular, hydroponics cultivation is of considerable interest to facilitate the production of high-quality green plants. However, establishing the planting operating systems in hydroponic cultivation may result in chronic problems such as the reproduction of harmful bacteria throughout the circulating culture fluid.

25 [0005] Present methods of sterilizing culture fluid include chemical, heat, and ultraviolet based sterilization. Ultraviolet sterilization is aimed at purifying the culture fluid using electromagnetic radiation, such as UV-C radiation.

[0006] However, none of the aforementioned sterilization methods consider the flow rate of fluid, which affects the efficacy of the disinfection of the fluid as it flows through a channels, conduits or pipes. In addition, none of the

aforementioned sterilization methods provide solutions that are easy to install and remove.

[0007] There exists a need for an improved apparatus, system and/or method for providing disinfection.

5 SUMMARY

[0008] The present disclosure provides a device, system and/or method for providing disinfection to a facility that contains infrastructure to facilitate fluid flow. Non-limiting examples of such a facility include a hydroponics system, swimming pools, water treatment systems, air-regulation systems, etc. The
10 inventor discovered that electromagnetic radiation such as ultraviolet (UV) radiation is able to achieve relatively better sterilization when directly irradiating microorganisms, and is also effective for the sterilization of flowing fluid owing to its high permeability. The inventor further noted that for effective sterilization of flowing fluids, sterilization has to be done in a relatively quick time with high
15 dosage/intensity of electromagnetic radiation.

[0009] According to one aspect of the disclosure, there is provided a disinfection module comprising: a housing having a transparent portion, the housing configured to allow fluid to flow longitudinally therethrough, the transparent portion configured to allow a disinfection radiation to pass
20 transversely therethrough; a cover portion mountable on the housing; and a radiation source attached to at least one of (i) the cover portion and (ii) an external surface of the transparent portion; wherein the disinfection module comprises a first end and a second end, the first end and the second end configured to be removably attached to at least one fluid conduit.

[0010] In some embodiments, the transparent portion is formed from or of quartz glass and the housing comprises a stainless-steel bracket shaped and dimensioned to receive the transparent portion. In some embodiments, the housing may comprise PVC, Aluminum, textile, soft PVC, rubber.

[0011] In some embodiments, the cover portion is formed from or of at least one of stainless steel, and aluminium.

[0012] In some embodiments, the at least one fluid conduit forms part of a hydroponics system, a swimming pool water circulation/cleaning system, a
5 water purification system, or an air regulation system.

[0013] In some embodiments, the cover portion has an internal surface layered with a reflective material comprising polished stainless steel, or wherein the internal surface is polished.

[0014] In some embodiments, at least one of the first end and the second
10 end comprises a pipe reducer.

[0015] In some embodiments, the disinfection module further comprises at least one intensity sensor arranged to detect the intensity of the radiation.

[0016] In some embodiments, the pipe has a diameter of 2 inches, 4 inches or 6 inches.

[0017] In some embodiments, the radiation source comprises a first row of
15 UV-LED units and a second row of UV-LED units. At least one of the first row of UV-LED units may be configured to emit a UV-C radiation. At least one of the second row of UV-LED units may be configured to emit a UV-C radiation.

[0018] According to another aspect of the disclosure there is a hydroponics
20 system having a at least one fluid conduit shaped and dimensioned to receive the disinfection module as described. The at least one fluid conduit may be an irrigation pipe configured or adapted for hydroponics culture fluid to flow therethrough.

[0019] According to another aspect of the disclosure there is a water
25 purification or treatment system having a at least one fluid conduit shaped and dimensioned to receive the disinfection module as described, wherein the at least one fluid conduit is an effluent water pipe.

[0020] According to another aspect of the disclosure there is an air regulation system having at least one fluid conduit shaped and dimensioned to receive the disinfection module as described, wherein the at least one fluid conduit comprises an air-regulation duct.

- 5 **[0021]** The irrigation pipe, water pipe, or air-regulation duct, as the case may be, can comprise at least one valve configured to control fluid flow through the pipe.

- [0022]** The system as described may further comprise a plurality of sensors arranged to detect an intensity of the emitted radiation from radiation source
10 and/or the flow rate of a fluid.

- [0023]** According to another aspect of the disclosure there is a method of manufacturing a disinfection module comprising the steps of: (a) forming a housing having a transparent portion, the housing configured to allow fluid to flow longitudinally therethrough, the transparent portion further configured to
15 allow a disinfection radiation to pass transversely therethrough; (b) forming a cover portion, the cover portion mountable on the housing; and (c) providing at least one slot on the cover portion, the at least one slot shaped and dimensioned to receive a radiation source, the radiation source comprises at least one light emitting diode; and (d) shaping a first end and a second end of
20 the pipe to be removably attached to a portion of at least one fluid conduit.

[0024] In some embodiments, the method further comprises the step of polishing an internal surface of the cover portion.

- [0025]** In some embodiments, the method further comprises the step of layering an internal surface of the cover portion with a polished stainless steel
25 or polished aluminum.

[0026] Other aspects of the disclosure will be apparent to those of ordinary skill in the art upon review of the following description of specific embodiments of the disclosure in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

5 **[0027]** Various embodiments are described, by way of example only, with reference to the accompanying drawings, in which:

[0028] FIG. 1A and 1B show an embodiment of a disinfection module for providing radiation-based sterilization or disinfection.

[0029] FIG. 2 shows a cross-sectional view of an embodiment of a disinfection module (without a cover portion) installed on a fluid conduit.

10 **[0030]** FIG. 3 shows a possible positioning of two rows of UV-C light emitting diodes (LED) in operation.

[0031] FIG. 4A to 4C show an application of the disinfection module for use with a hydroponics system.

15 **[0032]** FIG. 5A to 5C show an application of the disinfection module for use with an air-purification system.

[0033] FIG. 6A to 6D show another embodiment of a disinfection module in the form of a standalone air-sterilization unit.

[0034] FIG. 7 shows a flow chart of a method of manufacturing the disinfection module.

20 **[0035]** FIG. 8 shows a side view of another embodiment of a disinfection module incorporating a heat dissipation mechanism (fin-like structure) and a LED driver.

[0036] FIG. 9 shows a table of a possible implementation of the disinfectant module with operating parameters.

[0037] Other arrangements are possible, and it is appreciable that the accompanying drawings are not to be understood as superseding the generality of the preceding description of the disclosure.

5 DETAILED DESCRIPTION

[0038] Embodiments are described with reference to the accompanying drawings. The terminology used herein is for the purpose of describing particular embodiments only and is not intended to limit the scope of the present disclosure. Other definitions for selected terms used herein may be found within
10 the detailed description of the disclosure and apply throughout the description. Additionally, unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one ordinary skilled in the art to which the present disclosure belongs. Where possible, the same reference numerals are used throughout the figures for clarity and
15 consistency.

[0039] Throughout the specification, unless the context requires otherwise, the word “comprise” or variations such as “comprises” or “comprising”, will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

20 [0040] Throughout the specification, unless the context requires otherwise, the word “include” or variations such as “includes” or “including”, will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

[0041] Throughout the specification, unless the context requires otherwise,
25 the word “have” or variations such as “has” or “having”, will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

[0042] As used herein, the term “disinfect”, “disinfection”, “disinfecting”, “disinfectant” and variants refer to the use of a method to at least minimize

bacteria/germs/virus of an area/premise. The terms include methods via physical, chemical contact and/or via exposure to radiation (e.g., exposure to the area to specific radiation such as ultra-violet radiation). The term “fluid disinfection” may be construed as a disinfection method to minimize
5 bacteria/germs/virus in a fluid flowing within an area, such as within irrigation pipes.

[0043] As used herein, the term “associate”, “associated”, and “associating” indicate a defined relationship (or cross-reference) between at least two items. For instance, a plurality of devices (e.g., in the form of disinfection
10 device/apparatus) may be controlled by a central server/processor and hence ‘associated’ with the central server/processor. In a group of devices (e.g., disinfection apparatus with other disinfection apparatus and/or sensors), each device may interact with another device and hence be associated with one another.

[0044] As used herein, the term “network” can be any means of providing communication between one or more devices and/or content stored elsewhere. As used herein, network can be a personal area network, local area network, a storage area network, a system area network, a wide area network, a virtual private network, and an enterprise private network. The network can include
20 one or more gateways or no gateways. The network communication can be conducted via published standard protocols or proprietary protocols.

[0045] As used herein, communication of data through any network can be: (i) encoded or unencoded; (ii) encrypted or unencrypted; (iii) delivered via a wired network, a wireless network, or a combination of wired and wireless.
25 Wireless communication can be accomplished in any practical manner including via a Wi-Fi 802.11 network, a Bluetooth™ network, or mobile phone network (such as 3G, 4G, LTE, and 5G). The terms “connected”, “connected”, and “connecting” as used herein refer to a communication link between at least two devices and can be accomplished as discussed in this paragraph.

[0046] As used herein, the term “computing device” or “computer product” may be a single stand-alone computer such as a desktop computer or a laptop computer, a thin client, a tablet computer, or a mobile phone. The computing device may run a local operating system and store computer files on a local storage drive. The computing device may access files and application through a gateway to one or more content repositories, the content repository can host files and/or run virtual applications and generate a virtual desktop for the computing device.

[0047] As used herein, the term “server” or “processor” may include a single stand-alone computer, a single dedicated server, multiple dedicated servers, and/or a virtual server running on a larger network of servers and/or cloud-based service. The processor may include integrated circuit (IC) chips such as application specific integrated circuit (ASIC) chips.

[0048] As used herein, the term “database” may include one or more data repositories to store data and access data from a single stand-alone computer, a data server, multiple dedicated data servers, a cloud-based service, and/or a virtual server running on a larger network of servers.

[0049] As used herein, the term “sensor” or “sensors” include hardware sensors, software sensors and combinations of hardware and software sensors.

[0050] As used herein, the terms “ultraviolet-A” and “UV-A” include, but is not limited to ultraviolet radiation at a wavelength in the range of 315 to 405 nanometers (nm).

[0051] As used herein, the terms ultraviolet-C and “UV-C” include, but are not limited to all UV-C radiation, short-wave ultraviolet, FAR-UV, deep UV etc. A UV-C radiation may have a wavelength ranging from 200 to 280 nanometers (nm).

[0052] According to an aspect of the disclosure, there is a disinfection module comprising: a housing having a transparent portion, the housing configured to

allow fluid to flow longitudinally therethrough, the transparent portion configured to allow a disinfection radiation to pass transversely therethrough; a cover portion mountable on the pipe; and a radiation source attached to the cover portion or an external surface of the housing; wherein the disinfection module
5 comprises a first end and a second end, the first end and the second end configured to be removably attached to a portion of at least one fluid conduit. In some embodiments, the radiation source may comprise at least one light emitting diode.

[0053] In some embodiments, the at least one fluid conduit may be part of a
10 hydroponics system. In particular, the at least one fluid conduit may be an irrigation pipe shaped and dimensioned to allow hydroponics culture fluid or solution to flow therethrough. Accordingly, the disclosure may be implemented to keep hydroponic solution at a level of disinfection at a desired fluence (that is, radiation energy per surface area) sufficient to reduce or eliminate bacteria
15 or viruses at specific locations at a specified exposure time. In some embodiments, the at least one fluid conduit may be part of an indoor air-regulation system. In particular, the at least one fluid conduit may be an air-duct shaped and dimensioned to allow air to flow therethrough. Accordingly, the disclosure may be implemented to keep air at a level of disinfection at a desired
20 fluence (that is, radiation energy per surface area) sufficient to reduce or eliminate bacteria or viruses at specific locations at a specified exposure time.

[0054] FIGS. 1A and 1B show an embodiment of the disinfection device 100. When installed as part of at least one fluid conduit, the disinfection device 100 may be regarded as a disinfection module. The device 100 comprises a housing
25 102, and a cover portion 104. The housing may be shaped and dimensioned in accordance with the dimensions of the at least one fluid conduit, and in various embodiments may be a pipe. The at least one fluid conduit may form part of a hydroponics system, a swimming pool, a water purification system, or an air regulation system. Where the at least one fluid conduit is part of a hydroponics
30 system, the fluid may be hydroponics culture fluid. Where the at least one fluid conduit is part of a swimming pool, the fluid may be the pool water. Where the

at least one fluid conduit is part of an air regulation system, the fluid may be part of the influent air flow to the air regulation system. In some embodiments, the air regulation system may be an indoor air regulation system that may be positioned in an enclosed area (such as a room), or installed in a mode of transport, such as in a mass rapid transit.

[0055] The pipe 102 is hollow so as to allow fluid to flow longitudinally therethrough. The pipe 102 comprises a transparent portion 106. The transparent portion 106 may be formed from or of quartz glass or other suitable materials to allow disinfection radiation to pass transversely therethrough with minimal distortion. The transparent portion 106 may be referred to as a “sight glass”.

[0056] The pipe 102 may comprise one or more brackets 110 adapted to receive the transparent portion 106. The brackets 110 may be stainless-steel bracket shaped and dimensioned to receive the transparent portion 106.

[0057] The pipe 102 may have an IP65 rated enclosure to provide protection against low pressure water jets from any direction, as well as condensation and water spray. Such configuration may be suitable for outdoor enclosures.

[0058] The cover portion 104 may be formed from or of at least one of stainless steel and aluminium material. It is contemplated that other materials that are resistant to fluid and radiation corrosion may be suitable.

[0059] In some embodiments, the cover portion 104 has an internal surface layered with a reflective material comprising polished stainless steel. Alternatively, the internal surface may be polished.

[0060] The pipe 102 may comprise a first end 114 and a second end 116. In some embodiments, at least one of the first end 114 and the second end 116 comprises a pipe reducer 118.

[0061] In some embodiments, the disinfection module 100 further comprises at least one intensity sensor arranged to detect the intensity of the radiation.

[0062] In some embodiments, the disinfection module 100 comprises one or more dissolved oxygen sensors positioned to measure the amount of dissolved oxygen in the fluid flowing through the disinfection module 100.

[0063] In some embodiments, the pipe has a diameter of two (2) inches (50.8 millimetres), four (4) inches (101.6 millimetres) or six (6) inches (152.4 millimetres).

[0064] The cover portion 104 may comprise one or more slots adapted to receive a radiation source 120. In some embodiments, the radiation source 120 comprises at least one UV-LED units 108. In some embodiments, the radiation source 120 comprises the UV-LED units 108 arranged in the form of a first row of UV-LED units 122 and a second row of UV-LED units 124. The UV-LED units 122, 124 may be configured to emit one or more ultraviolet (UV) radiations, including, but not limited to, UV-A, UV-B and UV-C radiations. At least one of the first or second row of UV-LED units 122, 124 may be configured to emit a UV-C radiation. It is contemplated that other arrangements of the radiation source 120 are possible. For example, instead of two rows of UV-LED units, there may be one row of UV-LED units. Alternatively, there may be a single LED unit operable to provide UV irradiation to the fluid flowing longitudinally through the pipe portion 102. In other embodiments, the two rows of UV-LED units 122, 124 may be arranged to emit a combination of UV-A, UV-B and UV-C radiations. In yet other embodiments, the two rows of UV-LED units 122, 124 may be arranged to emit a combination of UV-A and UV-C radiations.

[0065] As an alternative or in addition to the radiation source 120 being received by the cover portion 104, the external surface of the pipe portion 102 may include slots to receive said radiation source 120.

[0066] FIG. 2 shows an embodiment the disinfection module 100 installed on an existing fluid conduit, without a cover portion 104. The disinfection module 100 may be positioned between two existing fluid conduits pipes 204 and 206. Each of the pipe 204, 206 have respective ends 204a, 206a adapted to couple with the first end 114 and second end 116 of the disinfection module 100. The

coupling may be facilitated by means such as screw threads, brackets, flanges etc. as known to a skilled person and will not be elaborated further. The pipes 204, 206 may include valves 210 to facilitate and control the flow of fluid therethrough. Valves 210 may include one-way valves or two-way valves.

5 **[0067]** The radiation source 120 may be positioned at a suitable portion such that radiation can be directed towards the fluid via the transparent portion 106. The radiation source 120 may be mounted on an existing facility (not shown) such as a wall or a ceiling of the facility. The radiation source 120 may be mounted on a Metal Core Printed Circuit Board (MCPCB). The MCPCB may
10 comprise at least one layer of insulated metal substrate laminate.

[0068] FIG. 3 shows two rows of UV-LED units 122, 124 that may be mounted on opposing sides of a steel cover portion 104. Each of the UV-LED units 124a, 124b, 124c, 124d are arranged in a manner such that the UV-LED units are not directly opposite the UV-LED units 122a, 122b, 122c, 122d. In
15 other words, the position of each of the UV-LED units 124a, 124b, 124c, 124d is offset or staggered with respect to 122a, 122b, 122c, 122d in a manner so as to achieve an overall coverage offset with a maximal exposure of the radiation to the fluid flowing within the pipe portion 102. It is contemplated that the two rows of UV-LED units 122, 124 may be mounted on opposing sides of the
20 transparent portion 106. It is further contemplated that either one of the rows 122, 124 may be mounted on the cover portion 104 and the other of the rows 122, 124 mounted on the transparent portion 106.

[0069] FIGS. 4A to 4C show an application of the disinfection module 100 for use with a hydroponics system 400 having existing PVC pipes 404a and 404b
25 for carrying hydroponics culture fluid. FIG. 4A shows an assembled view and FIG. 4B shows an exploded view of the various components for attaching or coupling the disinfection module 100 to the PVC pipes 404a and 404b. The components comprise a pair of adapters 406, a pair of reducers 408, and a valve 410. In FIG. 4B the cover portion 104 is removed to expose the
30 transparent portion 106. The embodiment shows the use of pipe reducers,

clamps and gaskets as means for coupling or connecting the housing 102 to existing pipe structures.

5 **[0070]** The pair of adapters 406 may each have a first end 406a and a second end 406b for coupling with the PVC pipes 404a, 404b and the reducer 408 or valve 410 respectively. The first end comprises screw threads for coupling with corresponding screw threads (not shown) found within an internal surface of the PVC pipes 404a and 404b. The adapter may include a seal or gasket portion shaped and dimensioned to interface with the reducer 408 or valve 410. The seal portion may have a similar dimension (e.g. diameter) for coupling with the
10 reducer 408 and/or valve 410.

[0071] The housing 102 may include a frame 140 for mounting a plurality of rows of UV-LED units. The frame 140 may be arranged in the form of a cage-like structure to surround the housing 102. Suitable slots may be formed on the frame 140 for receiving the rows of UV-LED units.

15 **[0072]** The pair of reducers 408 are adapted to couple the PVC pipes 404a, 404b which has a first diameter, with the housing 102, which has a relatively larger diameter than the first diameter. The valve 410 is configured to control the flow rate of hydroponics culture fluid through the housing 102 so as to achieve optimal disinfection of the flowing culture fluid.

20 **[0073]** FIG. 4C shows an embodiment of the hydroponics system 400 in operation. Culture fluid to be disinfected is fed through the PVC pipe 404a and the flow rate controlled by the valve 410, which is then passed through the housing 102 (see direction of culture fluid flow indicated by arrow 'A' in FIG. 4C). The disinfected culture fluid is then directed out to the PVC pipe 404b.

25 **[0074]** Although system 400 is described in the context of a hydroponics context, it is contemplated that the disinfection module 100 may be installed on any system for disinfection of flowing liquid having at least one fluid conduit shaped and dimensioned to receive the disinfection module 100 as described, wherein the at least one fluid conduit comprises one or more irrigation pipes.

Non-limiting examples include disinfection of swimming pool water, disinfection of wastewater, last mile disinfection for water purification systems, etc. The fluid conduit may be in the form of one or more irrigation pipes or effluent water pipes.

- 5 **[0075]** FIGS. 5A to 5C shows another embodiment wherein the disinfection module 100 is for use with an air-regulation system 500 having at least one fluid conduit shaped and dimensioned to receive the disinfection module 100 as described. The at least one fluid conduit comprises an air-regulation duct 504. The disinfection module 100 can be removably attached to existing air-regulation ducts 504. The air-regulation system 500 may be an existing air-regulation system found in the ceiling portions of an enclosed area such as a room or a train carriage. FIG. 5A shows an assembled view and FIG. 5B shows another assembled view of the various components for attaching or coupling the disinfection module 100 to the air ducts 504 with cover portion 104 removed.
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- 15 The air-regulation system 500 comprises a pair of air louvers 502, a plurality of air ducts 504, a pair of reducers 508, and a ventilation device 510.

- [0076]** The pair of air louvers 502 may be positioned proximate opposite end portions of the system 500 to filter particulates from the air flowing toward or from the ducts 504. The pair of air louvers 502 may each have fastening or coupling mechanisms such as screw threads (not shown) for attachment to the respective air ducts 504.
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- [0077]** Similar to the embodiment shown in FIG. 4A to 4C, the housing 102 may include a frame 140 for mounting a plurality of rows of UV-LED units. The frame 140 may be arranged in the form of a cage-like structure to surround the housing 102. Suitable slots may be formed on the frame 140 for receiving the rows of UV-LED units.
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- [0078]** The pair of reducers 508 are adapted to couple the air ducts 504, which have a second diameter, with the housing 102. The housing 102 has a relatively smaller diameter than the second diameter. The ventilation device 510 is configured to control the flow rate of air through the housing 102 so as
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to achieve optimal disinfection of the flowing air. In some embodiments, the ventilation device 510 may be in the form of a DC fan or a ducting fan.

5 [0079] FIG. 5C shows an embodiment of the air-regulation system 500 in the form of an air duct module in operation. Air to be disinfected is fed through the air louver 502 and the flow rate of the air passing through the may be controlled by the ventilation device 510 and/or one or more other external devices. The air is then passed through the housing 102. The disinfected air output from the housing 102 is then directed toward the duct 504 and out.

10 [0080] FIGS. 6A to 6D show another embodiment of a disinfection device or a device for disinfection 600. FIG. 6A show the disinfection device 600 as an air disinfection device with the disinfection portion exposed (without an outer cover). FIG. 6B shows the disinfection device with base portion exposed. FIGS. 6C and 6D show the air disinfection device in operation.

15 [0081] The disinfection device 600 comprises a first portion 602, a tower portion 604 and a second portion 606.

[0082] The first portion 602 comprises an inlet portion operable to draw air from an ambient environment. The first portion 602 may comprise an air louver having a plurality of air filter layers to filter particulates from the air entering the device 600. The plurality of air filter layers may include one or more of the
20 following types of filter: a HEPA filter, an electrostatic filter, a media filter, a pleated filter, a spun glass filter.

[0083] The tower portion 604 comprises a housing having a transparent portion, the housing shaped and dimensioned to receive drawn or filtered air from the first portion 602 and allow the drawn or filtered air to flow longitudinally
25 therethrough, the transparent portion configured to allow a disinfection radiation to pass transversely therethrough. A cover portion 608 may be mountable on the housing, and a radiation source 610 attached to at least one of (i) the cover portion 608 and (ii) an external surface of the transparent portion.

[0084] In the embodiment shown in FIGS. 6A to 6D, the radiation source 610 may be mounted on a frame 640 shaped and dimensioned to surround or partially surround the radiation source 610.

5 **[0085]** The second portion 606 comprises an outlet portion to urge disinfected air out of the device; wherein the housing provides disinfection based on a function of flow rate and intensity of radiation.

[0086] In some embodiments, the radiation source 610 may be attached to the cover portion 608 or an external surface of the housing. The radiation source 610 may comprise one or more rows of UV-LED units as described in
10 earlier embodiments.

[0087] In some embodiments, an inner surface of the cover portion 608 may be polished to enhance the reflectivity of the radiation incident on the inner surface.

[0088] The second portion 606 may include one or more ventilation devices
15 612 to urge any disinfected air out of the device 600. The device 600 may include some indicators, in the form of, for example LED strips 650 for providing a visual indication of the operational status of the device 600. The device 600 may include actuators 660 for switching between a plurality of operational states.

20 **[0089]** The various embodiments as described may further comprise a plurality of sensors arranged to detect an intensity of the emitted radiation from radiation source.

[0090] According to another aspect of the disclosure and with reference to FIG. 7, there is a method for manufacturing a disinfection module comprising
25 the steps of: (a) forming a pipe having a transparent portion, the pipe configured to allow fluid to flow longitudinally therethrough (step S702), the transparent portion configured to allow a disinfection radiation to pass transversely therethrough; (b) forming a cover portion, the cover portion mountable on the pipe (step S704); and (c) providing at least one slot on the cover portion, the at

least one slot shaped and dimensioned to receive a radiation source (step S706), the radiation source comprises at least one light emitting diode; and (d) shaping a first end and a second end of the pipe to be removably attached to a portion of at least one fluid conduit (step S708).

- 5 **[0091]** In some embodiments, the method further comprises the optional step of polishing an internal surface of the cover portion or the step of layering an internal surface of the cover portion with a polished stainless steel or polished aluminum (step S710).

- 10 **[0092]** Where stainless steel is used as a material for the cover 104, the stainless-steel grade SS304/SS316 may be used. In general, material having good thermal conductivity, non-corrosive, and unaffected by radiation such as UV may be contemplated.

- 15 **[0093]** It is appreciable that quartz glass, when used for the transparent portion 106, provides the disinfection device an optimum environment for performance. Quartz glass allows radiation to pass through with minimal distortion/ filtering in order to provide disinfection.

- 20 **[0094]** In some embodiments, tests may be conducted on the disinfection device with light intensity measurements with varying dimensions of pipe diameters from 2 inches to 8 inches (or 50.8 millimeters (mm) to 203.2 mm), and with flowrate up to 3 liters per minute. Peak radiometric intensity was observed with 0.3565mW/cm² with the 2 inch-tube diameter.

- 25 **[0095]** The use of UV-C LED units in the various embodiments may be operable to emit a wavelength of about 270 nanometers to 280 nanometers, and preferably at a wavelength of about 280 nanometers (nm). In some embodiments, the UV-C LED units may come in a hermetically sealed package for superior lifetime and reliability at high temperature and humidity. The hermetically sealed package protects the UV-C LED units from the potentially damaging effects of moisture, condensation and corrosive gases. Under challenging environmental conditions of 60°C ambient temperature and 90%

relative humidity, the use of UV-C LED with hermetic sealing may provide around 85% flux intensity after 8,000 hours.

5 **[0096]** In some embodiments, the UV LED units comprise optical lens to collimate UV radiation to intensify irradiance. The optical lens may be formed of or from highly UV resistant materials with high UV transmittance. The optical lens may collimate UV radiation to a beam angle of $110^{\circ} \pm 10^{\circ}$ to meet specific requirements, such as targeted irradiance within a specific time frame or otherwise.

10 **[0097]** Although the UV LED units have been described as one or two rows, more UV LED units/source may be used when the disinfection area required to achieve better disinfection results.

15 **[0098]** In some embodiments, where Metal Core Printed Circuit Board (MCPCB) are used, reliability and relatively good heat dissipation are achieved. The process of manufacturing MCPCB to create protrusions on the PCB board with the main goal of increasing/maximizing heat dissipation of the UV-LED units. In some embodiments as shown in FIG. 8, where the UV-LED units 108 are mounted on MCPCB, which is in turn mounted onto the tube cover 104, the tube cover 104 may be formed from or of aluminium or magnesium. The tube cover 104 may further be shaped to include a plurality of fins 802 so as to increase the overall surface area of the at least one disinfection module 100 for heat dissipation purpose. In the embodiment shown in FIG. 8, one or more of the UV-LED units 108 may be driven by a driver 804 to provide relatively ripple free constant direct current to the UV-LED units 108, for example, as taught in the PCT publication WO/2011/152795, PCT publication WO/2013/066270, and/or PCT publication WO/2019/032053.

20 **[0099]** In some embodiments, where the radiation source comprises one or more UV-C LED units, a plurality of UV-C radiation sensors may be provided and placed at various positions in the respective systems to detect the radiation intensities of UV-C at specific positions. The UV-C radiation sensors may include one or more radiation dosimeters, one or more UV-C electronic

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sensors, and/or one or more dosimeter cards.

[00100] In some embodiments, an inner surface of the transparent portion 106 may be coated with at least one layer of Titanium Dioxide (TiO₂) coating. In some embodiments, there may comprise multiple layers of TiO₂ coating. It is
5 envisaged when TiO₂ absorbs UV radiation from the UV-LED units 108, it will produce strong oxidizing agent: oxide anion (O²⁻) and Hydroxyl radicals (OH). When these oxidizing agents contact the fluid flowing through the transparent portion 106, the oxidizing agents may decompose organic compounds such as
10 viruses, bacteria, fungus, and volatile organic compound (VOC), turning them into water (H₂O) or other relatively harmless substances (CO₂) and dispersing the them into the atmosphere, i.e. photo-catalysis effect.

[00101] Also described here are disinfection systems for use in disinfecting a liquid or air medium where the systems may generally comprise at least one disinfection module 100 or standalone device 600. The disinfection
15 module or device may comprise a disinfection radiation source and a controller system configured to turn the disinfection radiation source between a plurality of states including, but not limited to, an on state, a standby state, a full intensity state, a partial intensity state, and an off state. The disinfection device may also comprise at least one motion sensor. In some variations, the sensor is used to
20 detect and measure movement. The sensing system configured to detect when a person is nearby or in an irradiation area of light.

[00102] In some embodiments, the system comprises a feedback network to stop emission of the UV-C radiation if the second level exceeds a predetermined threshold. A feedback network comprises a server
25 communicatively to at least one disinfection device via a network system, and a computer in communication with the server for controlling operational parameters of the disinfection device. The operational parameters may comprise a duration of a disinfection cycle (Scheduler), disinfection information comprises starts time and end time (Disinfection status), disinfection report
30 generation, report on power failure of disinfection devices.

[00103] In some embodiments, as an alternative or in addition to UV source, one or more UV-C laser diodes may be used.

[00104] In particular, the system can operate without need for personnel. From another perspective, the system may also be regarded as a system for
5 calibrating a UV-C radiation apparatus or device so that safe disinfection can carry out without adverse effects to human beings or animals.

[00105] It is contemplated that one or more computing devices may be used by a user to remotely control the disinfection device and/or receive data from the UV-C radiation sensors. The computing devices may be installed with
10 dedicated software applications colloquially referred to as 'apps' to remotely control the disinfection device or module.

[00106] The system may comprise a controller system, which may be configured to drive the disinfection module/device according to the disinfection methods. The devices may be connected via a network into a disinfection
15 system. The system may allow automatic operations of the disinfection system, manually adjust operational parameters via one or more user interface, and/or enable the system to analyse the transmitted data. The system may allow centralized monitoring, storage, or analysis of data that are connected to the network.

[00107] In some embodiments, where the system is a hydroponics system, a scheduler may be integrated with a Hydroponic Nutrient Solution piping system to manage the disinfection duration.

[00108] In some embodiments, the system may form part of an aquaculture system or farming in water.

[00109] FIG. 8 is a table showing some possible parameters in operation for effective disinfectant. For example, the UV-C LED units may be a 280
25 nanometres (nm) high radiant flux density UV-C LED. The UV-C LED unit may be operating at a rated power of 50 Watts (W), and has a driving current of 700 milli-amperes (mA). The lens may be a wide beam lens comprising a lens strip.

The radiant flux, irradiance and UV-C disinfection dosage at three duration of exposure, that is, 5 seconds, 0.7 seconds, and 11.15 seconds, are presented. The duration of exposure may be used to calibrate the flow rate(s) of fluid flowing through the housing and transparent portion so that the desired disinfection dosage is received by the fluid flowing therethrough.

[00110] In some embodiments, the fluid flow system comprises of Wi-Fi network protocol as the primary control and feedback interface. It enables monitoring of disinfection status; report generation after every completed disinfection. Facility Personnel to determine next action based on the successful or failure of the disinfection solution to complete the disinfection cycle. LED/Driver/System failure alert via notification or email to the facility department personnel, greatly reduce the downtime of the disinfection system which is crucial in the current situation / for daily disinfection activity. Management platform provides flexibility to facility personnel to schedule disinfection time for non-autonomous setup.

[00111] It is to be appreciated by the person skilled in the art that variations and combinations of features described above, not being alternatives or substitutes, may be combined to form yet further embodiments falling within the intended scope of the invention.

CLAIMS

1. A disinfection module comprising:
 - a housing having a transparent portion, the housing shaped and dimensioned to allow fluid to flow longitudinally therethrough, the transparent
 - 5 portion configured to allow a disinfection radiation to pass transversely therethrough;
 - a cover portion mountable on the housing; and
 - a radiation source attached to at least one of (i) the cover portion and (ii) an external surface of the transparent portion;
- 10 wherein the disinfection module comprises a first end and a second end, the first end and the second end configured to be removably attached to at least one fluid conduit.
2. The disinfection module of claim 1, wherein the transparent portion is formed from or of quartz glass and the housing is in the form of a pipe, the pipe
- 15 comprises a stainless-steel bracket shaped and dimensioned to receive the transparent portion.
3. The disinfection module of claim 1 or 2, wherein the cover portion is formed from or of at least one of stainless steel and aluminium.
4. The disinfection module of any one of the preceding claims, wherein the
- 20 fluid conduit is part of a hydroponics system, a swimming pool, a water purification system, or an air regulation system.
5. The disinfection module of any one of the preceding claims, claim 1, wherein the cover portion has an internal surface layered with a reflective material comprising polished stainless steel, or wherein the internal surface is polished.
- 25 6. The disinfection module of any one of the preceding claims, wherein at least one of the first end and the second end comprises a pipe reducer.

7. The disinfection module of any one of the preceding claims, further comprising at least one intensity sensor arranged to detect the intensity of the radiation.
8. The disinfection module of any one of the preceding claims, further comprising at least one dissolved oxygen sensor arranged to detect the amount of dissolved oxygen flowing through the disinfection module before and/or after disinfection.
9. The disinfection module of any one of the preceding claims, wherein the radiation source comprises a first row of UV-LED units and a second row of UV-LED units.
10. The disinfection module of claim 9, wherein at least one of the first row of UV-LED unit emits a UV-C radiation, or wherein at least one of the second row of UV-LED unit emits a UV-C radiation.
11. The disinfection module of any one of the preceding claims, wherein an inner surface of the transparent portion configured to contact the fluid flowing longitudinally therethrough is coated with at least one layer of Titanium dioxide.
12. A hydroponics system having at least one fluid conduit shaped and dimensioned to receive the disinfection module of any one of claims 1 to 11.
13. A water purification or treatment system having at least one fluid conduit shaped and dimensioned to receive the disinfection module of any one of claims 1 to 11.
14. An air regulation system having at least one fluid conduit shaped and dimensioned to receive the disinfection module of any one of claims 1 to 11.
15. A aquaculture system having at least one fluid conduit shaped and dimensioned to receive the disinfection module of any one of claims 1 to 11.
16. The system of any one of claims 12 to 15, wherein the at least one fluid conduit comprises at least one valve configured to control fluid flow through the

pipe.

17. The system of any one of claims 12 to 16, further comprising a plurality of sensors arranged to detect an intensity of the emitted UV-C radiation from the radiation source.

5 18. A method of manufacturing a disinfection module, the method comprising the steps of: (a) forming a pipe having a transparent portion, the pipe configured to allow fluid to flow longitudinally therethrough, the transparent portion configured to allow a disinfection radiation to pass transversely therethrough;

(b) forming a cover portion, the cover portion mountable on the pipe;

10 (c) providing at least one slot on the cover portion or the pipe, the at least one slot shaped and dimensioned to receive a radiation source; and

(d) shaping a first end and a second end of the pipe to be removably attached to a portion of at least one fluid conduit.

15 19. The method of claim 18, further comprising a step of polishing an internal surface of the cover portion.

20. The method of claim 18 or 19, further comprising a step of layering an internal surface of the cover portion with a polished stainless steel or polished aluminium.

20 21. The method of any one of claims 18 to 20, further comprising a step of coating an inner surface of the transparent portion configured to contact the fluid flowing longitudinally therethrough with at least one layer of Titanium dioxide.

22. A device for disinfection comprising:

a first portion having an inlet portion operable to draw air;

25 a housing having a transparent portion, the housing shaped and dimensioned to receive drawn air from the inlet portion and allow the drawn air

to flow longitudinally therethrough, the transparent portion configured to allow a disinfection radiation to pass transversely therethrough;

a cover portion mountable on the housing;

5 a radiation source attached to the cover portion or an external surface of the housing; and

a second portion having an outlet portion to urge disinfected air out of the device; wherein the housing provides disinfection according to a function of flow rate of the air and intensity of radiation of the radiation source.

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