

DISINFECTION DEVICE AND SYSTEM FOR PLACEMENT IN OR NEAR A HEAT EXCHANGER UNIT

CROSS-REFERENCE TO RELATED APPLICATION

- 5 **[0001]** The application claims the benefit of priority of Singapore Patent Application No. 10202301880W, filed 30 June 2023, the content of which is hereby incorporated by reference in its entirety for all purposes.

TECHNICAL FIELD

- 10 **[0002]** The present disclosure relates to a disinfection device and system for placement in or near a heat exchanger unit. The disinfection device is suitable, but not limited to, providing disinfection to one or more heat exchangers in public vehicles.

15 BACKGROUND

- [0003]** 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
20 in any jurisdiction as of the priority date of the application.

- [0004]** The use of public transportation has always been a cornerstone of urban mobility, providing an efficient and cost-effective means for moving large numbers of people. However, the relatively high density of passengers and the continuous turnover of individuals entering and exiting these vehicles present
25 significant challenges in maintaining sanitary conditions. The spread of infectious diseases, such as influenza, the common cold, and more recently, COVID-19, may be exacerbated in these environments due to the relatively close proximity of passengers and frequent contact with contaminated surfaces.

- [0005]** Traditional methods of disinfection, including manual cleaning with
30 chemical agents, have been employed to mitigate the spread of pathogens.

While effective to some extent, these methods have several drawbacks. Manual cleaning is labor-intensive, time-consuming, and cannot guarantee complete coverage of all surfaces, especially in high-traffic areas and hard-to-reach spots. Additionally, frequent use of chemical disinfectants can lead to health risks for both passengers and cleaning staff, as well as potential damage to the surfaces being cleaned.

[0006] Electromagnetic radiation such as ultraviolet (UV) light has been recognized for its germicidal properties and has been utilized in various disinfection applications. In particular, UV-C radiation, with wavelengths between 200-280 nanometers, may be effective in inactivating a broad spectrum of microorganisms, including bacteria, viruses, and fungi, by damaging their DNA and RNA, thus preventing them from replicating. UV-C disinfection systems have been implemented in healthcare settings, water treatment facilities, and HVAC systems. However, their application in mass rapid transit systems has been relatively limited.

[0007] The implementation of UV-C disinfection in public transportation systems, such as mass rapid transit systems, may present some unique challenges. These systems must be designed to operate within the spatial constraints of transit vehicles and must be robust enough to withstand the vibrations and movements inherent to such environments. Additionally, the disinfection module must be capable of operating without direct exposure to passengers, to prevent harmful UV-C exposure, while still ensuring comprehensive disinfection of the vehicle's surfaces.

[0008] To address these challenges, there exists a need for an effective, automated, and safe disinfection module that can be integrated into mass rapid transit vehicles, ensuring continuous and thorough disinfection without interfering with regular operations or posing health risks to passengers and staff.

SUMMARY

[0009] The present disclosure provides a disinfection device and system for

placement in a heat exchanger or in the proximity of a heat exchanger, with improved efficiency and effectiveness. The present invention aims to fulfil the need by providing a disinfection device or module specifically designed for the unique requirements of mass rapid transit systems.

5 **[0010]** According to one aspect of the disclosure, there is a disinfection module for placement in, or in the proximity of, a heat exchanger unit, the disinfection module comprising at least one disinfection source, the at least one disinfection source configured to emit electromagnetic radiation; an attachment
10 plate for attachment to a section of the heat exchanger unit; and at least one disinfection source receiver comprising a first portion extending from the attachment plate, and a second portion detachably connected to the first portion and extending at an angle from the first portion; wherein the second portion is configured to receive the at least one disinfection source and direct the electromagnetic radiation toward a surface of the heat exchanger unit.

15 **[0011]** In some embodiments, the second portion comprises a bracket shaped and dimensioned to receive the at least one disinfection source, and a support stand for the bracket to rest thereon.

20 **[0012]** In some embodiments, the at least one disinfection source receiver is sized and dimensioned to be positioned such that the disinfection source irradiates the surface of an evaporator coil of the heat exchanger unit.

[0013] In some embodiments, the disinfection module further comprises a protective cover, the protective cover made of a material which allows the electromagnetic radiation to pass therethrough.

25 **[0014]** In some embodiments, the protective cover (144) comprises a transparent cover, the transparent cover made of quartz glass.

[0015] In some embodiments, the at least one disinfection source comprises a plurality of light-emitting diodes, and wherein the electromagnetic radiation is an ultraviolet-A (UV-A) radiation and/or an ultraviolet-C (UV-C) radiation.

[0016] In some embodiments, the disinfection module further comprises a

hinge that allows adjustment of the angle between the second portion and the first portion within a range of 10 degrees to 50 degrees.

5 **[0017]** In some embodiments, the at least one disinfection source is an LED assembly, the LED assembly comprises a housing, the housing comprises reflective coating on an inner surface of the housing to enhance the irradiation efficiency of the UV light source, wherein the light reflective material optionally comprises polished aluminium, polished aluminium alloy and/or Polytetrafluoroethylene.

10 **[0018]** In some embodiments, the polished aluminium alloy comprises at least 80% aluminium, and is preferably an aluminium alloy comprising aluminium, chromium, and magnesium.

15 **[0019]** In some embodiments, the disinfection module further comprises at least one disinfection source configured as at least one LED assembly capable of emitting UV-A electromagnetic radiation, wherein the LED assembly comprises a frame, the frame comprises a plurality of fins coated with a photo-catalytic material.

[0020] In some embodiments, the frame is positioned along an irradiation path of the LED assembly.

20 **[0021]** In some embodiments, the photo-catalytic material comprises titanium dioxide.

[0022] In some embodiments, the disinfection module further comprises a control unit, the control unit includes a timer for scheduling the operation of the at least one disinfection source.

25 **[0023]** In some embodiments, the control unit includes a data logging feature to record the operational history of the at least one disinfection source.

[0024] In some embodiments, the control unit is configured to send alerts to a remote monitoring system when maintenance or replacement of the at least one disinfection source is required.

5 [0025] In some embodiments, the disinfection module further comprises one or more sensors, wherein the one or more sensors include at least one of the following: a temperature sensor for monitoring the temperature of the evaporator coil, a humidity sensor for monitoring the humidity levels proximate to the evaporator coil.

10 [0026] In some embodiments, the control unit is configured to activate the at least one disinfection source based on a predetermined temperature threshold detected by the temperature sensor, and/or activate the at least one disinfection source based on a predetermined humidity threshold detected by the humidity sensor.

15 [0027] According to another aspect of the present disclosure, there is provided a system for disinfection of an evaporator coil of a heat exchanger unit, the system comprising at least one disinfection module as described; the at least one disinfection module positioned such that the longitudinal axis of the bracket is substantially parallel to a surface of the evaporator coils.

20 [0028] In some embodiments, the at least one disinfection module further comprises at least one LED assembly capable of emitting UV-A electromagnetic radiation, and wherein the LED assembly comprises a frame coated with a photo-catalytic material, wherein the frame comprises a plurality of fins coated with a photo-catalytic material.

25 [0029] According to another aspect of the present disclosure, there is provided a method for providing disinfection of an evaporator coil of a heat exchanger unit, comprising the steps of: providing at least one disinfection module as described; positioning the at least one disinfection module such that the longitudinal axis of the bracket is substantially parallel to a surface of the evaporator coils.

[0030] 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.

5 BRIEF DESCRIPTION OF THE DRAWINGS

[0031] Various embodiments are described, by way of example only, with reference to the accompanying drawings, in which:

- 10 - FIGS. 1A to 1C show embodiments of a device for providing disinfection in the form of a disinfection module suitable for placement in or near a heat exchanger unit.
- FIG. 2 shows an exploded view of the device of FIGS. 1A to 1C.
- FIG. 3 is a schematic block diagram showing an IoT system including the device, for the provision of disinfection to a heat exchanger.
- 15 - FIG. 4 is a device operating status block diagram of the device according to an embodiment of the present disclosure.

[0032] 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.

20 DETAILED DESCRIPTION

[0033] 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
25 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 consistency.

[0034] 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.

[0035] 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.

[0036] Throughout the specification, unless the context requires otherwise, 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.

[0037] As used herein, the term “disinfection”, “disinfecting”, “disinfectant” and variants refer to the use of a method to at least minimize bacteria/germs/virus/pathogens 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 electromagnetic radiation such as ultra-violet radiation). The term “air disinfection” may be construed as a disinfection method to minimize bacteria/germs/viruses in the air flowing within the area/premise. The term “surface disinfection” may be construed as a disinfection method to minimize bacteria/germs/viruses on a surface of an object within an area/premise.

[0038] 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 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.

[0039] As used herein, the term “network” can be any means of providing communication between one or more devices and/or content stored elsewhere.

5 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 one or more gateways or no gateways. The network communication can be conducted via published standard protocols or proprietary protocols.

10 **[0040]** 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. Wireless communication can be accomplished in any practical manner including via a Wi-Fi 802.11 network, a Bluetooth™ network, or mobile phone
15 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.

[0041] As used herein, the term “computing device” may be a single stand-alone computer such as a desktop computer or a laptop computer, a thin client,
20 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.

25 **[0042]** 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.

[0043] 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.

5 **[0044]** As used herein, the term “sensor” or “sensors” include hardware sensors, software sensors and combinations of hardware and software sensors.

[0045] 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
10 nanometers (nm).

[0046] As used herein, the terms ultraviolet-C and “UV-C” include, but is not limited to all UV-C radiation, short-wave ultraviolet, FAR-UV, deep UV etc. A UV-C radiation may be at a wavelength of 200 to 280 nanometres (nm).

[0047] As used herein, the term “Heating, Ventilation, and/or Air
15 Conditioning” (HVAC) refers broadly to any system capable of providing at least one of heating, ventilation, and air conditioning functions. An example is an air-conditioner capable of regulating temperature in an enclosed area, such as a train cabin.

[0048] As used herein, the term “module” refers to, or forms part of, or include
20 an Application Specific Integrated Circuit (ASIC); an electrical/electronic circuit; a combinational logic circuit; a field programmable gate array (FPGA); a processor (shared, dedicated, or group) that executes code; other suitable hardware components that provide the described functionality; or a combination of some or all of the above, such as in a system-on-chip. The term module may
25 include memory (shared, dedicated, or group) that stores code executed by the processor.

[0049] As used herein, the term “vehicle” includes a motor-powered vehicle, for example a vehicle having 2, 3, 4, or more wheels. Examples of the vehicle include a passenger car, a truck, a bus, a lorry, an aircraft, or a rail vehicle, for
30 example, a locomotive. In some embodiments, the vehicle may be a mass rapid

transit train. The term vehicle may further include autonomous vehicles.

[0050] Disclosed herein is a disinfection device and system for automatically disinfecting air passing through a heat exchanger using suitable electromagnetic radiation, such as, but not limited to, ultraviolet (UV) radiation.

5 UV radiation may be provided in the form of emitters as a means for providing disinfection that is intelligently controlled and to enable the protection of human beings and/or animals.

[0051] It was realized that although the use of UV radiation for disinfection is known, many known UV emitters do not provide effective disinfection. In addition, the efficacy of present UV emitters may not be properly measured. The inventor is motivated by the need to develop a device for disinfection that can achieve high log reduction, a measurement that is used to express the relative number of living microbes that are eliminated by disinfection. Based on this, a log 2 reduction will see a 99 percent reduction, or microbe reduction by a factor of 100, and so on.

[0052] In the following, embodiments will be described in detail.

[0053] FIG. 1A to FIG. 1C illustrates a disinfection module 100 according to an aspect of the disclosure. The disinfection module 100 may be suitable for placement in, or in the proximity of, a heat exchanger unit 1000. The heat exchanger unit 1000 may form part of an HVAC system. The HVAC system may be an HVAC system of a public transportation network, such as, but not limited to, a mass rapid transit (MRT) system. In some embodiments, the heat exchanger unit 1000 may comprise one or more evaporator coils. The one or more evaporator coils may be configured or arranged to remove heat from the surrounding air using a refrigerant that runs through heat-conducting tubes, such as copper tubings.

[0054] The disinfection module 100 comprises at least one disinfection source 102, the at least one disinfection source 102 configured to emit (an) electromagnetic radiation; an attachment plate 104 for attachment to a portion or section of the heat exchanger unit 1000; and at least one disinfection source

receiver configured to receive the at least one disinfection source 102; the at least one disinfection source receiver comprises a first portion 108 extending from the attachment plate 104, and a second portion 110 for receiving the at least one disinfection source 102; wherein the second portion 110 is removably attached or detachably connected to the first portion 108 and extending at an angle from the first portion 108, the second portion 110 orientated in a manner such that the at least one disinfection source 102 emit the electromagnetic radiation toward a surface of the heat exchanger unit 1000. Directing electromagnetic radiation towards the surface of the heat exchanger unit 1000 may constraint most of the electromagnetic radiation within the heat exchanger unit 1000 and therefore avoid harmful electromagnetic radiation from being directed to human beings.

[0055] In the embodiments shown in FIG. 1A to FIG. 1C, there comprise two first portions 108 extending from the attachment plate 104, and two second portions 110 extending from the two respective first portions 108.

[0056] As shown in FIG. 1A, the two second portions 110 may be extended at an angle with respect to the longitudinal axis of the first portions 108. In some embodiments, the angle may be an obtuse or acute angle. In some embodiments, the first portion 108 and the second portion 110 may be integrally molded. Alternatively, the second portion 110 may be hingedly connected to the first portion 108, such that the angle may be adjustable. In some embodiments, the angle between the second portion 110 and the first portion 108 is adjustable in a range of 10 degrees to 50 degrees, or 100 degrees to 150 degrees.

[0057] FIG. 1B shows the possible deployment of the disinfection module 100 in a heat exchanger unit 1000. The heat exchanger unit 1000 may be a standalone heat exchanger unit, or may form part of a heat exchange system.

[0058] The second portion 110 may comprise a bracket 112 shaped and dimensioned to receive the at least one disinfection source 102. The bracket 112 may be supported by a support stand 114. In the embodiment shown in FIG. 1B, the support stand 114 is an extension of the bracket 112 with a bend

and fold back portion forming a base for the disinfection module 100. In an alternative embodiment, there may comprise an independent or standalone support 114 connected to the bracket 112 via fasteners such as bolts and nuts, hinges, screws, etc.

5 [0059] The at least one disinfection source receiver may be sized and dimensioned to be positioned such that the disinfection source 102 irradiates one or more evaporator coils 1002 of the heat exchanger unit 1000. As illustrated in FIG. 1C, the angle between the first portion 108 and the second portion 110 may be fix on manufacture, or adjusted, as the case may be, such
10 that the irradiation of the evaporator coils 1002 may be maximized. In some embodiments, the disinfection module 100 may be positioned such that the longitudinal axis of the bracket 112 is substantially parallel to a surface of the evaporator coils 1002.

[0060] FIG. 2 shows an exploded perspective view of various components forming the disinfection module 100, according to another embodiment of the
15 present disclosure. The disinfection module 100 comprises the attachment plate 104 in the form for attachment to a portion of the heat exchanger unit 1000. In the embodiment shown in FIG. 2, the attachment plate 104 comprises slots 122 for attachment to a part of the heat exchanger 1000 using, for
20 example, fasteners such as bolts and nuts, and/or screws. The attachment plate 104 further comprises a plurality of holes sized and dimensioned to receive fasteners 124, the plurality of holes formed on various positions to facilitate attachment of the first portion 108. Two first portions 108 may be attached to the attachment plate 104 via the fasteners 124. Slots 126 may be
25 formed on each of the first portion 108 to receive the bolts/screws 124, which may then may be secured in a position along the slots 126 using nuts.

[0061] Each first portion 108 may further comprise a gap 128. The gap 128 may be formed on the first portion 108, the gap 128 shaped and dimensioned to receive the second portion 110. The second portion 110 may be attached to
30 the first portion using a coupling mechanism that may include slots, flanges as known to a skilled person, and which will not be elaborated further. The second

portion 110 may comprise a bracket 112 shaped to receive the at least one disinfection source 102.

[0062] The at least one disinfection source 102 may comprise a plurality of light-emitting diodes (LEDs). In the embodiment shown in FIG. 2, the disinfection source 102 may be an LED assembly 140, the LED assembly 140 comprising electrical circuitry and multiple LEDs arranged in rows and columns to form one or more LED arrays. The LED assembly 140 may comprise LEDs capable of emitting an ultraviolet-A (UV-A) radiation and/or an ultraviolet-C (UV-C) radiation. The LED assembly 140 may include electrical connectors 142 to a direct current (DC) provider 150, the DC provider 150 operable to provide DC current and voltage to the LED assembly. In some embodiments, the DC provider 150 may be a LED driver configured to produce relatively "ripple free" electrical current may used. Examples of such a driver are disclosed in the PCT patent publications WO/2011/152795, WO/2015/122848 to Opulent Electronics International Pte. Ltd. The "ripple free" current is defined to be less than 5% from the specified rated current.

[0063] In some embodiments, the LED assembly 140 may comprise a housing 141, a protective cover 144, and a heat sink 146. In some embodiments, the protective cover 144 may be made of a material which allows the electromagnetic radiation to pass therethrough. In some embodiments, the protective cover 144 may comprise a transparent cover, the transparent cover made of or formed from quartz glass.

[0064] The heat sink 146 may be formed using heat-conducting material to dissipate heat from the LED arrays quickly. The heat-conducting material may include metallic alloys. The heat sink 146 may comprise multiple fin-like structures to maximize surface area for the purpose of heat dissipation. In addition to the heat sink assembly 146, a metal core printed Circuit board (MCPCB) to further enhance heat dissipation may be provided. Such MCPCB may include the creation of one or more protrusions on printed circuit boards to increase heat dissipation.

[0065] The LED assembly 140 may comprise one or more gaskets 148. The

gaskets 148 may parameterize the LED assembly 140 such as to form a seal with the protective cover 144 to protect the LED arrays from external elements. The gaskets 148 and the protective cover 144 may form a seal against external environment and may be designed to meet the 154 requirements for obtaining an IP68 rating.

[0066] Each LED assembly 140 may be sized and shaped to be securely received by the respective bracket 112. In some embodiments, the bracket 112 may comprise one or more snap-fit mechanisms for receiving the LED assembly 140. In some embodiments, electrical wires, may be provided through the gaps 128 for connection to the electrical connectors 142.

[0067] In some embodiments, an inner surface of the housing 141 may be coated with light reflective material to enhance the irradiation efficiency of the UV light source, wherein the light reflective material optionally comprises polished aluminium, polished aluminium alloy and/or Polytetrafluoroethylene. In some embodiments, the polished aluminium alloy comprises at least 80% aluminium, and preferably is an aluminium alloy comprising aluminium, chromium, and magnesium.

[0068] In some embodiments, the at least one UV-C emitter is operable to emit a UV radiation having wavelength of about 270 nanometers to 280 nanometers.

[0069] In some embodiments, where the LED array comprises one or more UV-A LEDs, the LED assembly 140 may include an additional frame 154 positioned along an irradiation path of the UV-A LEDs. The frame 154 may comprise a plurality of fins coated with a photo-catalytic material. In some embodiments, the photo-catalytic material may comprise titanium dioxide.

[0070] In some embodiments, the DC provider 150 may include intelligent control features. The LED driver may include a control unit, such as a controller, the control unit enabled with data communication devices to communicate with one or more sensors, as well as with a user control module arranged in an Internet of Things (IoT) architecture.

[0071] FIG. 3 shows an Internet of Things (IoT) architecture or system 300 designed to optimize data management and communication between IoT devices, a gateway, and servers, which may include cloud servers. The architecture may be used to facilitate reliable data transmission, efficient data processing, and robust security measures. It comprises sensor nodes, communication protocols, gateways, cloud services, and a management platform. The IoT architecture 300 may include a photocatalyst module 302, the photocatalyst module 302 with a smart LED driver, a controller 304, one or more sensors 306, a gateway 308, a management platform 310, and one or more end-user computer devices 312.

[0072] In various embodiments, the photocatalyst module 302 may be the device 100 having at least one LED assembly 140 capable of emitting UV-A electromagnetic radiation, and having the frame 154 coated with a photocatalytic material. In some embodiments, the photocatalytic material may comprise titanium dioxide.

[0073] In various embodiments, the controller 304 may be configured to operate the device 100 and receive data from one or more sensors 306.

[0074] The one or more sensors 306 may be hardware sensors and/or software sensors configured to collect data from the environment. The one or more sensors 306 may include one or more temperature sensors 306a, one or more humidity sensors 306b, one or more radiation intensity sensors 306c. It is appreciable one or more other sensors (not shown), such as voltage sensors, current sensors, motion sensors, and/or one or more light sensors, may be added to monitor environmental conditions. The temperature sensor may be configured for monitoring the temperature of the evaporator coil, and the humidity sensor for monitoring the humidity levels proximate to the evaporator coil. In some embodiments, at least one radiation intensity sensor 306c may be positioned in the vicinity of the heat exchanger unit 1000 to detect changes in radiation intensity and to monitor if an unacceptable level of radiation intensity has been detected outside the heat exchanger unit 1000.

[0075] The gateway 308 may be an Internet or Intranet gateway allowing the

controller 304 and the management platform 310 to communicate with each other, via Wi-Fi routers and/or Ethernet cables.

5 **[0076]** The management platform 310 may comprise a connectivity module 321, a device management module 322, a data management module 323, an analytics module 324, an edge computing module 325, and an app development module 326. Each of the modules in the management platform 310 may receive and send data via an application programming interface (API).

10 **[0077]** The management platform 310 may provide a user interface for monitoring and controlling the IoT system. In some embodiments, the management platform 310 may provide a dashboard, which may include a web-based or mobile dashboard for real-time monitoring of sensor data and system status. In some embodiments, the user interface may be configured for manually adjusting the operational settings of the at least one disinfection .

15 **[0078]** In some embodiments, the management platform 310 may provide tools to manage the one or more sensors and gateways. Such tools may include firmware updates and configuration settings.

[0079] In some embodiments, the management platform 310 may provide an alert system. The alert system may allow one or more users to customize alerts and notifications for predefined conditions or anomalies.

20 **[0080]** In some embodiments, the management platform 310, via the analytics module 324, may be used to generate reports and insights from historical data.

25 **[0081]** In some embodiments, the disinfection module 100 may be controlled via the controller/control unit of the smart driver 150. FIG. 4 shows an embodiment of the disinfection module 100 in operation. The operation may be in response to a schedule 402, a manual instruction 404, and detection of an error 406.

[0082] The disinfection module 100 may be configured to operate according to the schedule 402, the schedule 402 may, in turn, be pre-defined and sent to

the controller of the driver 150. In some embodiments, one or more operation states of the disinfection module 100 may correspond to the schedule 402. For example, if an "in schedule" instruction 411 is positively detected by the controller, the at least one disinfection source 102 is switched on and may be adjusted 412 up to 100%. This corresponds to an active state 413. Where an
5 "out of schedule" instruction 414 is positively detected by the controller, the at least one disinfection source 102 further detects if there is an updated instruction sent from the end-user computer devices 312, and where there are no further instructions sent from the end-user computer devices 312, thus
10 corresponding to a "no count uplink" state 415, then the schedule 402 is set to remain at the last updated status 416.

[0083] In the manual mode 404, the disinfection module 100 receives instructions to turn on 421 the at least one disinfection source 102, and set the disinfection module 100 to an active state 422, or to turn off 423 the at least one
15 disinfection source 102 and set the disinfection module 100 to a standby state 424.

[0084] In the error detection mode 406, upon receiving an error notification 406, the controller of the driver 150 may be configured to detect if the Wi-Fi module is functioning. In a positive determination that the Wi-Fi module is not
20 functioning 431, the controller checks if there is a missing uplink 432 for more than a defined threshold number, e.g. 5 times. Upon detecting that the missing uplink exceeds the defined threshold number, the controller of the driver 150 deems the Wi-Fi module to be disconnected 433. The controller proceeds to detect if the root cause can be found 432. If the root cause cannot be found
25 434, an error report is submitted 435, and servicing of the disinfection module 100 is requested 436.

[0085] In a positive determination that the Wi-Fi module is still functioning 437, the controller determines that the error is non-connection related 438, submits an error report 439, and request for servicing 440.

30 **[0086]** In some embodiments, the control unit includes a data logging feature to record the operational history of the at least one disinfection source 102.

[0087] In some embodiments, the control unit is configured to send alerts to a remote monitoring system when maintenance or replacement of the at least one disinfection source 102 is required.

5 [0088] In some embodiments, the control unit is configured to activate the at least one disinfection source 102 based on a predetermined temperature threshold detected by the temperature sensor, and/or activate the at least one disinfection source 102 based on a predetermined humidity threshold detected by the humidity sensor.

10 [0089] In some embodiments, the further comprising a safety mechanism that deactivates the at least one disinfection source 102 when the housing 141 is opened.

15 [0090] In some embodiments, there comprises two disinfection modules 100 a first disinfection module 100 positioned to irradiate a first surface of the evaporator coil, and a second disinfection module 100 to irradiate the second surface of the evaporator coil. The first surface and the second surface may be opposing surfaces.

[0091] In some embodiments, the disinfection module 100 further comprises a battery backup system to provide power to the at least one disinfection source 102.

20 [0092] In some embodiments, the connectivity module 311 may include Zigbee, Bluetooth modules for transmitting data. The connectivity module 311 may also support relatively longer-range communication protocols such as LoRaWAN, and NB-IoT for communication over longer distances directly to the cloud or gateways.

25 [0093] In some embodiments, one or more LED lamp unit of the LED array may comprise a lens unit, the lens unit may be formed of or from optically transparent polymers, preferably liquid silicone rubber (LSR). In some embodiments, each lens unit may be removably attached to the LED lamp unit, which may allow the lens to be exchanged to achieve different amounts of light
30 attenuation.

[0094] It is contemplated that in some embodiments, one of the plurality of LED units, for example, a first LED unit, may be configured to emit UV-C radiation, while another LED unit, for example, a second LED unit, may be configured to emit a UV-A radiation. In another embodiment, all the LED units
5 104 may be configured to emit UV-A radiation. In yet another embodiment, all the LED units may be configured to emit UV-C radiation. With reference to FIG. 2, it may be contemplated that one of the LED assembly 140 may be configured to emit UV-C radiation, and the other LED assembly 140 may be configured to emit UV-A radiation.

10 [0095] In some embodiments, the housing 141 may be formed from a die-cast process or an additive manufacturing process.

[0096] It is contemplated that the entire housing may be formed from an aluminum alloy, such as, but not limited to, a 5052-aluminium alloy.

[0097] According to another aspect of the present disclosure, there is a
15 system for disinfection for a train cabin. The train cabin may be a cabin of a mass rapid transit transport. The system may include the heat exchanger unit 1000 for treating the air within the train cabin, at least one device (one or more device) 100 as previously described, and the IoT architecture as depicted in FIG. 3. In some embodiments, the system may comprise a processor
20 configured to toggle each of the plurality of LED assembly 140 between an off state and an on state. The processor may be part of a remote server and is arranged in data or signal communication with each of the disinfection device 100 so as to transmit control signals to the disinfection devices and/or receive data signals from the disinfection devices. Examples of control signals include
25 turn on signals, switch off signals, and dimming signals. Examples of data signals include radiation intensity measurements, electrical voltage, electrical current, operating temperature associated with each disinfection module 100. In this regard, it is appreciable that each disinfection module 100 can include
30 one or more of the following sensors: voltage sensor, current sensor, temperature sensor, pressure sensor, radiation intensity sensor, etc.

[0098] The disinfection system can operate without personnel. From another perspective, the system enables safe disinfection can carry out without adverse effects to human beings.

5 [0099] It is contemplated that one or more computing devices may be used by a user to remotely control the device and/or receive data from the UV-C radiation sensors.

10 [00100] In general, the present disclosure provides for the use of electromagnetic radiation suitable for providing disinfection, such as UV-A and/or UV-C radiation, and can be integrated into the HVAC systems of train carriages to disinfect the air. This helps in reducing airborne pathogens, providing cleaner air for passengers. Continuous air disinfection may be particularly beneficial during peak hours when trains are crowded.

15 [00101] Described is a device, system, and method for reducing the risk of bacteria or virus transmission on contact surfaces and/or transmission in the air. The device described herein may be capable of automatically cleaning the contact surfaces using irradiation, such as UV irradiation.

20 [00102] In some embodiments, the system may comprise a wireless network using a Wi-Fi network protocol as the primary control and feedback interface. Such a network enables monitoring of disinfection status and generates a report after every completed disinfection. Authorized personnel, such as a facility personnel, may be deployed to determine a next action based on the success or failure of the disinfection solution to complete the disinfection cycle. Any faults or failures associated with the device, driver or system may be sent via alert via notification or email to the facility department personnel. This greatly reduce the downtime of the disinfection system which is crucial in the current situation / for daily disinfection activity. A management platform or interface may be provided flexibility to facility personnel to schedule disinfection time for non-autonomous setup.

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[00103] It is contemplated that one or more computing devices may be used by a user to remotely control the device 100 and/or receive data from the sensors.

[00104] 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 present disclosure.

CLAIMS

1. A disinfection module (100) for placement in, or in the proximity of, a heat exchanger unit (1000), the disinfection module (100) comprising
 - at least one disinfection source (102), the at least one disinfection source
 - 5 (102) configured to emit electromagnetic radiation;
 - an attachment plate (104) for attachment to a section of the heat exchanger unit (1000); and
 - at least one disinfection source receiver comprising a first portion (108) extending from the attachment plate (104), and a second portion (110)
 - 10 detachably connected to the first portion (108) and extending at an angle from the first portion (108);
 - wherein the second portion (110) is configured to receive the at least one disinfection source (102) and direct the electromagnetic radiation toward a surface of the heat exchanger unit (1000).
- 15 2. The disinfection module (100) of claim 1, wherein the second portion (110) comprises a bracket (112) shaped and dimensioned to receive the at least one disinfection source (102), and a support stand (114) for the bracket (112) to rest thereon.
- 20 3. The disinfection module (100) of claim 1 or 2, wherein the at least one disinfection source receiver is sized and dimensioned to be positioned such that the disinfection source (102) irradiates the surface of an evaporator coil (1002) of the heat exchanger unit (1000).
- 25 4. The disinfection module (100) of any one of the preceding claims, further comprises a protective cover (144), the protective cover (144) made of a material which allows the electromagnetic radiation to pass therethrough.
5. The disinfection module (100) of claim 4, wherein the protective cover (144) comprises a transparent cover, the transparent cover made of quartz glass.

6. The disinfection module (100) of any one of the preceding claims, wherein the at least one disinfection source (102) comprises a plurality of light-emitting diodes (LEDs), and wherein the electromagnetic radiation is an ultraviolet-A (UV-A) radiation and/or an ultraviolet-C (UV-C) radiation.
- 5 7. The disinfection module (100) according to any one of the preceding claims, further comprising a hinge that allows adjustment of the angle between the second portion (110) and the first portion (108) within a range of 10 degrees to 50 degrees.
8. The disinfection module (100) of any one of the preceding claims, wherein
10 the at least one disinfection source (102) is an LED assembly (140), the LED assembly (140) comprises a housing (141), the housing (141) comprises reflective coating on an inner surface of the housing (141) to enhance the irradiation efficiency of the UV light source, wherein the light reflective material optionally comprises polished aluminium, polished aluminium alloy and/or
15 Polytetrafluoroethylene.
9. The disinfection module (100) of claim 8, wherein the polished aluminium alloy comprises at least 80% aluminium, and is preferably an aluminium alloy comprising aluminium, chromium, and magnesium.
10. The disinfection module (100) of claim 1, further comprising at least one
20 disinfection source (102) configured as at least one LED assembly (140) capable of emitting UV-A electromagnetic radiation, wherein the LED assembly (140) comprises a frame (154), the frame (154) comprises a plurality of fins coated with a photo-catalytic material.
11. The disinfection module (100) of claim 10, wherein the frame (154) is
25 positioned along an irradiation path of the LED assembly (140).
12. The disinfection module (100) of claim 10 or 11, wherein the photo-catalytic material comprises titanium dioxide.

13. The disinfection module (100) of any one of the preceding claims, further comprising a control unit, the control unit includes a timer for scheduling the operation of the at least one disinfection source (102).
14. The disinfection module (100) of claim 13, wherein the control unit includes
5 a data logging feature to record the operational history of the at least one disinfection source (102).
15. The disinfection module (100) of claim 13 or 14, wherein the control unit is configured to send alerts to a remote monitoring system when maintenance or replacement of the at least one disinfection source (102) is required.
- 10 16. The disinfection module (100) of any one of the preceding claims, further comprises one or more sensors, wherein the one or more sensors include at least one of the following: a temperature sensor for monitoring the temperature of the evaporator coil, a humidity sensor for monitoring the humidity levels proximate to the evaporator coil.
- 15 17. The disinfection module (100) of claim 16, wherein the control unit is configured to activate the at least one disinfection source (102) based on a predetermined temperature threshold detected by the temperature sensor, and/or activate the at least one disinfection source (102) based on a predetermined humidity threshold detected by the humidity sensor.
- 20 18. A system for disinfection of an evaporator coil (1002) of a heat exchanger unit (1000), the system comprising

at least one disinfection module (100) according to claim 1; the at least one disinfection module positioned such that the longitudinal axis of the bracket (112) is substantially parallel to a surface of the evaporator coils (1002).
- 25 19. The system according to claim 18, wherein the at least one disinfection module (100) further comprises at least one LED assembly (140) capable of emitting UV-A electromagnetic radiation, and wherein the LED assembly (140) comprises a frame (154) coated with a photo-catalytic material, wherein the frame (154) comprises a plurality of fins coated with a photo-catalytic material.

20. A method for providing disinfection of an evaporator coil (1002) of a heat exchanger unit (1000), comprising the steps of:

providing at least one disinfection module (100) according to claim 1;

5 positioning the at least one disinfection module such that the longitudinal axis of the bracket (112) is substantially parallel to a surface of the evaporator coils (1002).