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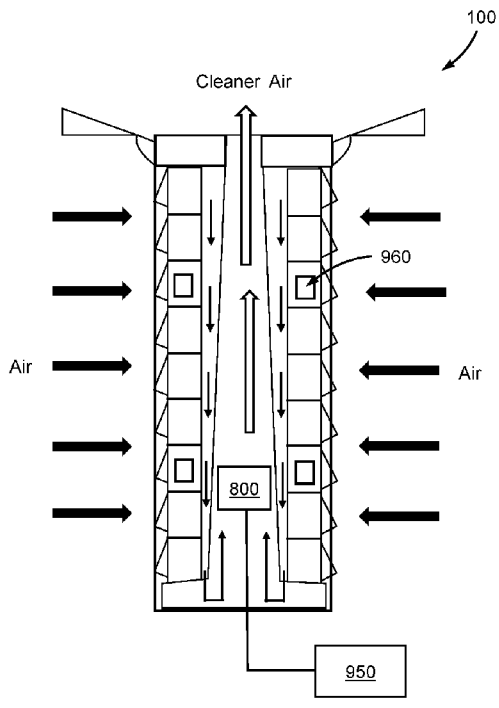


FIG. 8

(57) Abstract: An active air purification system includes a chamber and an outer wall The chamber includes a tank and a shaft. The tank is disposed at a base of the system. The tank defines a tank cavity with a tank inlet and a tank outlet. The shaft includes a shaft wall. The shaft wall defines a shaft channel. The shaft channel extends from the tank cavity along a reference axis towards a top of the system. The outer wall is coupled to the chamber to cooperatively define an outer channel between the outer wall and an exterior surface of the shaft wall. The shaft wall is inclined relative to the reference axis to define an increasingly smaller cross-sectional area for the outer channel towards the tank cavity and to correspondingly define an increasingly smaller cross-sectional area for the shaft channel away from the tank cavity.

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ACTIVE AIR PURIFICATION SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of priority to the Singapore application no. 10202300027V filed January 4, 2023, the contents of which are hereby incorporated by reference in their entirety for all purposes.

TECHNICAL FIELD

[0002] This application relates generally to green wall systems, and more specifically to green wall systems with air purification functions.

BACKGROUND

[0003] A green wall generally consist of a building façade with vegetation growing thereon. While green walls may have a certain aesthetic appeal, they are plagued with a variety of maintenance issues, including but not limited to root balls, watering difficulties, soil concerns, pest problems, and damage to the building façade. In addition, indoor green wall installations have to deal with mold formation and floor damage issues.

SUMMARY

[0004] In one aspect, the present application discloses a system including a chamber and an outer wall. The chamber includes a tank and a shaft. The tank is disposed at a base of the system. The tank defines a tank cavity with a tank inlet and a tank outlet. The shaft includes a shaft wall. The shaft wall defines a shaft channel. The shaft channel extends from the tank cavity along a reference axis towards a top of the system. The outer wall is coupled to the chamber to cooperatively define an outer channel between the outer wall and an exterior surface of the shaft

wall. The shaft wall is inclined relative to the reference axis to define an increasingly smaller cross-sectional area for the outer channel towards the tank cavity and to correspondingly define an increasingly smaller cross-sectional area for the shaft channel away from the tank cavity.

[0005] The outer channel may be characterized by a smaller cross-sectional area at the tank inlet than the cross-sectional area of the shaft channel at a tank outlet. The shaft channel may be characterized by a smaller cross-sectional area at a shaft outlet than at a shaft inlet. The shaft outlet may be defined at the top of the system. The shaft inlet may interface with a tank outlet at the tank. The outer wall may include external openings to receive air flow into the outer channel via the external openings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Various embodiments of the present disclosure are described herein with reference to the following drawings:

[0007] FIG. 1 is a perspective view of a system according to some embodiments of the present disclosure;

[0008] FIG. 2 is a perspective view of a chamber of the system of FIG.1;

[0009] FIG. 3A is a side view of the system of FIG. 1;

[0010] FIG. 3B is a magnified view of a part of FIG. 3A;

[0011] FIG. 4A is a perspective view of two opposing outer walls of the system of FIG. 1;

[0012] FIG. 4B is a side view of one façade of FIG. 4A;

[0013] FIG. 4C is a front view of one façade of FIG. 4A;

[0014] FIG. 5A is a front view of a plant holder module of FIG. 4C;

[0015] FIG. 5B is a perspective view of the plant holder module of FIG. 5A;

[0016] FIG. 5C is a top view of the plant holder module of FIG. 5A;

[0017] FIG. 5D is a bottom view of the plant holder module of FIG. 5A;

[0018] FIG. 6A is a top view of the system of FIG. 1;

[0019] FIG. 6B is a perspective view of a lighting module according to the system of FIG. 6A;

[0020] FIG. 7 is a perspective view of a fan / disinfection module according to the system of FIG. 6A;

[0021] FIG. 8 is a schematic diagram of the system showing the airflow directions when the system is in an operational state;

[0022] FIG. 9A is a perspective view of another embodiment of the system;

[0023] FIG. 9B is a side view of the system of FIG. 9A;

[0024] FIG. 10 is a schematic diagram of the system according to various embodiments of the present disclosure; and

[0025] FIG. 11 to FIG. 14 are images of prototypes according to various embodiments of the system.

DETAILED DESCRIPTION

[0026] The following detailed description is made with reference to the accompanying drawings, showing details and embodiments of the present disclosure for the purposes of illustration. Features that are described in the context of an embodiment may correspondingly be applicable to the same or similar features in the other embodiments, even if not explicitly described in these other embodiments. Additions and/or combinations and/or alternatives as described for a feature in the context of an embodiment may correspondingly be applicable to the same or similar feature in the other embodiments.

[0027] In the context of various embodiments, the articles “a”, “an” and “the” as used with regard to a feature or element include a reference to one or more of the features or elements.

[0028] In the context of various embodiments, the term "about" or "approximately" as applied to a numeric value encompasses the exact value and a reasonable variance as generally understood in the relevant technical field, e.g., within 10% of the specified value.

[0029] As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0030] System

[0031] To aid understanding and not to be limiting, various embodiments of a green wall system 100 is described below. For the sake of brevity, the terms "system" and "green wall system" may be used interchangeably in the present disclosure.

[0032] FIG.1 is a perspective view of one embodiment of the system 100 suitable for use indoors or outdoors. The system 100 may be variously shaped and dimensioned to suit the environment where the system 100 is used.

[0033] In some embodiments, the system 100 has a generally rectangular prism shape with at least one major face presented by an outer wall 400. In the example of FIG. 1, the system has two outer walls 400 of height (h) and length (l). In the example of FIG. 1, the system 100 has two sides 105 of depth (d). The length (l) is preferably longer than the depth (d).

[0034] For convenient reference, a reference axis 101 may be defined as an imaginary line extending vertically through a centre of the system 100. For convenient reference, the reference plane 102 may be defined as an imaginary plane generally parallel to the at least one outer wall 400/104. Alternatively, the reference plane 102 may be defined to coincide with a plane of mirror symmetry of the system 100.

[0035] The system 100 may include at least one first outer wall 400 in which each of the at least one outer wall 400 includes an area suitable for receiving and/or supporting one or more plants.

[0036] In some embodiments, the system 100 may be "single-sided" in which the system 100 does not have mirror symmetry about the reference plane 102. For example, in a "single-sided" configuration, the system 100 may have only one outer wall 400 having an area suitable for receiving and/or supporting one or more plants.

[0037] In some embodiments, the system 100 may be "double-sided" in which the system 100 includes a second outer wall 402 opposing the first outer wall 401. The first outer wall 401 (shown in FIG. 1) of the system 100 and the second outer wall 402 (hidden from view in FIG. 1) of the system 100 may be configured similarly to one another in a "double-sided" example.

[0038] The system 100 includes a chamber 300 and at least one outer wall 400. The chamber 300 and the at least one outer wall 400 may be shaped to complementarily mate and couple with one another. When assembled, the chamber 300 and the at least one outer wall 400 form a generally upright structure that can be used as a room divider.

[0039] In various embodiments of the system 100, the one or more outer walls 400 may include one or more plant holder modules 600. Optionally, the system 100 may include a lighting module 700. The lighting module 700 may be disposed proximal to the top 111 of the system 100.

[0040] Optionally, a base 112 of the system 100 may directly rest on the floor. Optionally, rollers or wheels may be provided at the base 112, e.g., to enable convenient re-location or re-orientation of the system 100. Optionally, the base 112 of the system 100 may be disposed on a track-and-rail for slidable movement, e.g., to serve as a slidable door. Optionally, the system 100 may form a part of various non-load bearing building elements, e.g., doors, room dividers, etc.

[0041] Chamber

[0042] FIG. 2 is a perspective view of the chamber 300 according to the embodiment of FIG. 1. In some embodiments, the chamber 300 may define the height (h) of the system 100.

[0043] The chamber 300 may include a tank 320. The tank 320 may be disposed proximal to the base 112 of the system 100. The tank 320 defines a tank cavity 324 that is suitable for holding a volume of water or other liquids. In some embodiments, the tank 320 may define the length (l)of the system 100 and the depth (d) of the system 100. The tank 320 includes a tank inlet 322 and a tank outlet 326. The tank outlet 326 is also the shaft inlet 342. The tank cavity 324 opens to the shaft channel 344 via the tank outlet 326/shaft inlet 342.

[0044] The chamber 300 may include a shaft 340. The shaft 340 may be disposed above the tank 320. The shaft 340 is hollow and defines a shaft channel 344 therein. The shaft channel 344 may be configured to extend generally along the reference axis 101. The shaft channel 344 is defined by an interior shaft wall 345. The shaft channel 344 is open to the external environment via a shaft outlet 346. The shaft outlet 346 is at the top 111 of the system. The shaft outlet 346 is preferably oriented upward. The shaft inlet 342 is adjacent to the tank 320 and proximal to the base 112. The shaft channel 344 has a larger cross-sectional area at the shaft inlet 342 than at the shaft outlet 346. The shaft channel 344 may have a tapering profile extending from the shaft inlet 342 to the shaft outlet 346. Each of the interior shaft wall 347 and the exterior shaft wall 349 is correspondingly inclined relative to the reference axis 101.

[0045] The shaft 340 may be configured such that the tank inlet 322 is adjacent to the exterior shaft wall 349 and such that the tank inlet 322 is outside of the shaft channel 344. The interior shaft wall 347 may extend into the tank cavity 324 by a protrusion 348 that extends along an entire length of the tank inlet 322.

[0046] Outer Wall

[0047] FIG. 3A is a side view of the system of FIG. 1 showing the relative positions of the chamber 300 and two outer walls 400. FIG. 3B is a magnified view of a wall unit 410 to more clearly show the airflow paths in the vicinity.

[0048] The inner surface 404 of the outer wall 400 (which also defines part of the outer

channel 414) is not a flat surface but is an uneven surface with various sub-channels 413 of various dimensions. The sub-channels 413 are generally not aligned or not oriented parallel to the reference axis 101. It may be considered counterintuitive to configure the outer wall 400 with an uneven inner surface 404 (e.g., with a plurality of sub-channels 413) as conventional thinking may believe that a flat and smooth surface is conducive to a more controllable (e.g., laminar) flow of air. In various embodiments of the present disclosure, the inner surface 404 of the outer wall 400 is preferably uneven, e.g., likely to result in more turbulent airflow near the inner surface 404. For example, the inner surface 404 may have a three-dimensional configuration defined by features, such as but not limited to, wall units 410 and plant holder modules 600.

[0049] According to various embodiments of the present disclosure, the external wall 400 is not a unitary solid planar article. For example, the external wall 400 may be an assembly of one or more wall units 410 and a plurality of plant holder modules 600 supported by a frame, which is coupled to the chamber 300. For example, the external wall 400 may be an array of wall units 410 or a stack of wall units 410, as illustrated in FIGS. 4A to 4C. Each wall unit 410 may be coupled with at least one other adjacent wall unit 410. The wall units 410 located at the periphery of the array may be coupled to the chamber 300. In some embodiments, the outer wall 400 may be formed by one unitary wall unit 410 on which is coupled a plurality of plant holder modules 600. In some embodiments, the outer wall 400 may be formed by a plurality of wall units 410, each wall unit 410 being coupled with one or more than one plant holder module 600. In some embodiments, the outer wall 400 may be described as an array or a stack in which each wall unit 410 of the array includes one or more plant holder modules 600 disposed on a respective wall unit 410.

[0050] Referring again to FIG. 3A and FIG. 3B, the wall unit 410 may be coupled to one side of the chamber 300 such that at least a part of an outer channel 414 is defined between the

shaft 320 and a wall unit 410. Additionally, at least a part of the outer channel 414 is defined between the shaft 320 and a plant holder module 600. Alternatively described, the outer channel 414 is defined between the exterior shaft wall 349 and the inner surface 404 of the outer wall 400, in which the inner surface 404 includes an uneven configuration formed by an array of one or more wall units 410 and/or one or more plant holder modules 600.

[0051] The outer channel 414 may extend from the top 111 of the system 100 and alongside the shaft 340. The outer channel 414 is closed at the top 111 of the system 100. The outer channel 414 terminates at an outer channel outlet 416 that is also the tank inlet 322. The outer channel 414 has a larger cross-sectional area at the top 111 than nearer the base 112 where the outer channel outlet 416 (which is also the tank inlet 322) leads into the tank cavity 324.

[0052] The exterior shaft wall 349 defines one side of the outer channel 414. An opposing side of the outer channel 414 corresponds to the inner surface 404 of the outer wall 400. The external face 406 of the outer wall 400 is preferably vertically disposed, e.g., parallel or substantively parallel to the reference axis 101.

[0053] The tank cavity 324 directly opens to the interior of the system 100, e.g., within the space defined by two opposing outer walls 400 (in a double-sided configuration). For example, the tank cavity 324 opens directly to the outer channel 414 and does not directly open to the external environment via the external face 406 of the outer wall 400.

[0054] Merely to aid understanding, airflow of the system in use may be described in sections. It will be understood that actual flow of air is neither sectional nor in discrete blocks, but rather air flow is more of a continuous fluid movement. For example, a first airflow path section 210 may be directed from the external environment (environment external to the system 100) toward the outer wall 400, oriented generally from the outer surface 406 of the outer wall 400 towards the inner surface 404 of the outer wall 400. A second airflow path section 220 may be in various directions, from the outer wall 400 (e.g., one or more of the plant holder module

600), through along a first section 210, through vents of the plant holder module along a second section 220, downwards along the outer channel 414 along a third section 230, redirected at the tank cavity 324 in a fourth section 240 and moved upward along the shaft channel 344 along a fifth section 250, and exiting the system 100 via the shaft outlet 346.

[0055] Air enters the system 100 through/ between the leaves and roots of plants disposed in the outer wall 400. The air after being "pre-purified" by plants (e.g., removal of total volatile organic compounds (TVOC,) Formaldehyde, odors, etc.) flows through the path towards the tank cavity 324. Near the surface of the water in the tank cavity 324 (water tank), the air flow direction is inverted and moves towards the fan/disinfection module 800. The reversal in air flow direction on the surface of water further purifies the particulate matter (PM) in the air, thereby acting like a simplified mechanical cyclone. As described, the system 100 enables a multi-stage 'purification' for a volume of air drawn into the system 100 (each air intake into the system 100).

[0056] The tapering of the outer channel 414 from a larger cross-sectional area to a smaller cross-sectional area results in a speeding up of the air flow near the base 112, and facilitate a jet-like effect at the outer channel outlet 416. This promotes the drawing in or ingestion of more air from outside the system, through the plant system, and into the outer channel 414. Together with the turbulent air flow paths about the plant support module 600. After the reversal of direction of the air flow, the air in the shaft channel 344 is propelled along by the fan/disinfection module 800, aided by the tapering shape of the shaft channel 344.

[0057] The wall unit 410 may contribute towards sealing the sides 105 and the top 111 (except at the shaft outlet 346) of the system 100, so as to maintain the desired airflow patterns inside the system 100. The substantially sealed structure "forces" air intake primarily or exclusively through the outer wall 400. When the outer wall 400 is populated with plants, the air intake into the system 100 is primarily or exclusively through the gaps between the leaves

and roots of the plants.

[0058] The wall units 410 can also serve to hide the various piping, electrical systems, physical supporting structures, etc. In some examples, piping and electrical systems may run through gaps between the wall units 410. In some examples, the wall unit sidewalls 430 or panels 730 can serve to cover electrical conduits. In some examples, the top cover (FIG. 6B) can serve to cover water piping conduits. The flexibility in configuring different numbers of wall units 410 in different array configurations gives the user a choice of options. The use of modular outer walls provides more opportunities to create more space in the outer channel 414 such that one or more fans may be disposed in the outer channel 414.

[0059] Plant Holder Module

[0060] The same wall 400 may include different types of wall units 410. Each wall unit 410 may include one or more than one plant holder module 600. The entire outer wall 400 can be easily scaled up or scaled down by adding or by removing wall units 410 from the outer wall 400. The wall units 410 need not be substantially rectilinear in shape. The plant holder module 600 need not have a generally cylindrically-shaped sleeve 610. The wall unit 410 and/or the plant holder module 600 may have various geometrical shapes, symmetrical shapes, and/or asymmetrical shapes.

[0061] In the example illustrated in FIG. 5A to FIG. 5D, the plant holder module 600 includes a sleeve 610 with a first sleeve end 601 and a second sleeve end 602. The first sleeve end 601 may be coupled to the wall unit 410. For example, the first sleeve end 601 may be substantially closed by a shelf 420 of the wall unit 410. The first sleeve end 601 or the shelf 420 may be punctured by one or more drain holes 422. The second sleeve end 602 is open, e.g., the second sleeve end 602 may define an external opening 640.

[0062] A sleeve axis 106 or an axis extending through a geometrical center of the sleeve 610 is angularly displaced or tilted at an angle (α) relative to the reference axis 101. In comparison

with the second sleeve end 602, the first sleeve end 601 (external opening 640) is disposed higher or at a greater elevation. Each sleeve 610 forms a tilted receptable suitable to receive at least one plant. The plant may be disposed in a sleeve 610 with the roots (of the plant) nearer the second sleeve end 602 and with the leaves (of the plant) nearer or projecting beyond the first sleeve end. If there is excess water provided to the plant (in the plant holder modules), e.g., if the plants are watered from the outer surface of the outer wall 400, and if there is any run off water, the water will tend to run off inward and eventually flow down (e.g., in the outer channel 414), through the tank inlet 322 and into the tank cavity 324. It is expected that ruff off liquids flowing down the outer surface 406 of the wall 400 is minimal or it can be substantially avoided.

[0063] FIG. 5C is a top view of the plant holder module 600 / wall unit 410. FIG. 5D is a bottom view of the plant holder module 600 / wall unit 410. As illustrated, the upper part (air section) of the sleeve 610 is cut through with a plurality of vents 620 (air section slits). The lower part (water section) of the sleeve 610 has no vents 620 or significantly fewer vents 620. The vents 620 may be slit-shaped openings that spiral or partially wrap about the sleeve 610. The vents allow a relatively large area of exposure of air through the plant system without over evaporation or loss of moisture from the media.

[0064] Lighting Module

[0065] FIG. 6A is a top view of the system 100 of FIG. 1 showing the shaft outlet 346 in relation to other parts of the system 100. FIG. 6B is a perspective view of the lighting module 700. The outer channel 424 and/or the shaft channel 344, and the air flow patterns, may be at least partly defined by parts of the lighting module. As shown in FIG. 6A and FIG. 6B, the system 100 may include a lighting module 700 to facilitate photosynthetic activity in the plants disposed in the plant holder modules 600.

[0066] The lighting module 700 may include one or more eave or overhang 712 correspondingly coupled to the chamber 300 so that each overhang 712 projects beyond the

outer wall 400 of the system 100. For example, one or more lights 702 may be mounted under an overhang 712 so that the lights 702 in operation can radiate the plants disposed in the various plant holder modules 600 below the overhang 712. The perimeter of the overhang 712 may include a shade 714 to reflect the light towards the plants.

[0067] In some embodiments, the lighting module 700 may include panels 730 to close the outer channels 344 from the sides 105 of the system 100. In some embodiments, the lighting module 700 may include top panels 720 to close the outer channel 414 at the top 111 of the system 100. In some embodiments, the lighting module 700 may include top panels 720 that define the shaft outlet 346.

[0068] The lighting module 700 not only preserves the aesthetics of the whole system 100, it further enhances the photosynthetic activities of the plants (mounted to the system 100) independently of indoor light conditions. The photosynthetic activities of the plants play a part in the cleaning of the air through phytoremediation.

[0069] Fan / Disinfection Module

[0070] The air flow paths or the movement of air in/near the system 100 may be effected with the aid of one or more fans disposed in the shaft channel 344. As illustrated in FIG. 6A and FIG. 7, a fan / disinfection module 800 may be provided in the shaft channel 344 near the base 112. The fan / disinfection module 800 may include one or more fans 810 disposed in the shaft channel 344 to drive air flow from within the shaft channel 344 out via the shaft outlet 346. In some embodiments, a plurality of fans 810 may be distributed along the length (l) of the system 100 or along the length of the shaft channel 344.

[0071] In operation, as the fans draw air from the tank cavity 324 upward along the shaft channel 344 and out through the shaft outlet 346, air will be drawn from outside the system 100, through the outer wall 400, into the outer channel 414, and down towards the tank cavity 324.

[0072] In various embodiments, the one or more fans 810 may be controllably operated to provide maximum air flow in the system 100 and/or within an acceptable level of noise. The one or more fans 810 may be operated in tandem or independently. The respective fan speeds of the one or more fans 810 may be controlled according to a method in which the fan speed is variable, e.g., pulse width modulation (PWM) control schemes, etc.

[0073] In some embodiments, operating the one or more fans 810 at the maximum fan speed may result in an uncomfortable level of noise for an indoor quiet working environment. The fan speed may be adjustable in response to a detected noise level (e.g., using a noise sensor) and/or air flow rates (e.g., using an air flowmeter).

[0074] For example, a plurality of fans 810 may be distributed along the length of the fan / disinfection module 800, e.g., distributed spaced apart at regular intervals along the length of the shaft channel 344 or along the length of the system 100, as shown in FIG. 3C. In various embodiments, the one or more fans 810 are configured to operate to enable relatively uniform air ingestion (via the plant holder modules 600) in different parts of the outer wall 400.

[0075] In some embodiments, the fan / disinfection module 800 includes one or more disinfection elements 820. One or more disinfection elements 820 may include, but is not limited to, one of the following examples or a combination of any two or more of the following examples: ultra-violet (UV) disinfection radiation, plasma, silver (Ag^+) ions, ozone, titanium oxide (TiO_2) coatings, etc. For example, The disinfection element 820 may be disposed in the air flow path before or after the fan 810 such that the air may be disinfected as it passes by.

[0076] The fan / disinfection module 800 is preferably disposed relatively low in the system 100 so lower the noise (from the fans 810) and to increase the flow rate through the fans via a suction of air. The fan / disinfection module 800 is positioned to avoid ingesting (taking in or drawing in) water from the tank cavity below the fans 810.

[0077] In some embodiments, the disinfection module 800 may controllably adjusted in terms of its height, in addition to controllable adjustments to the fan speed. This fan / disinfection module 800 may be mounted for slidable movement up or down the the shaft and/or the tank 320.

[0078] The system may be described as an integration of a disinfection system, an air flow system, and a water feed system. The system includes a plurality of dissimilar systems cooperatively integrated to provide clean air that is relatively clean of bacteria and/or virus.

[0079] Air Purification

[0080] FIG. 8 is a schematic cross-sectional side view of the system 100 implemented as a demand-based active biological air purification system. Sensors 960 may be disposed at suitable locations in the system 100 to measure the airflow rate of the incoming air, the levels of carbon dioxide, the presence of volatile solvents, etc. The system 100 includes a controller module 950 that is configured to acquire the sensor readings, determine one or more parameters to be adjusted in the fan/disinfection module 800 (e.g., fan speed, switching on/off of selected disinfection elements, etc.)

[0081] Biological air filtration refers to a process where plants are used to clean the air. The dirty air is filtered by a process called phytoremediation. Phytoremediation is a set of processes where the plants break down complex molecules to plant-usable ones. Plants can facilitate biodegradation of organic pollutants by stabilizing pollutants in soil by preventing erosion, leaching, or runoff, or by converting pollutants to less bioavailable forms in a processed call phytostabilization. Plants can degrade organic pollutants directly via their own enzymatic activities inside tissues, a process called phytodegradation. After uptake in plant tissue (leaf, or plant transpiration) certain pollutants can leave the plant in volatile form by a process called phytovolatilization.

[0082] Plants can also be used to extract pollutants and accumulate them in their tissues, followed by harvesting of the (above ground) plant material.

[0083] Gaseous pollutants can also be degraded through stomata. The above described mechanisms are governed by physical–chemical processes such as: gaseous pollutant absorption into solution, adsorption on the plants, plant capillary diffusion from roots to the upper plant level, xylem cell walls or cellulose groups interactions.

[0084] Air enters the system through/ between the leaves and roots of the plants disposed on the outer wall 400. The air after being purified by plants (e.g., removal of total volatile organic compounds (TVOC,) Formaldehyde, odors, etc.) flows through the path towards the tank cavity 324. Near the surface of the water in the tank cavity 324 (water tank), the air flow direction is inverted and moves towards the fan/disinfection module 800. The reversal in air flow direction on the surface of water further purifies the particulate matter (PM) in the air, thereby acting like a simplified mechanical cyclone. The air is then disinfected by the disinfection section 800 (either one or a combination of UV disinfection, plasma/ silver (Ag^{+}) ions, ozone, titanium dioxide (TiO_2) coating, etc.

[0085] Lightweight expanded clay aggregate (LECA) or rock wool-based hydroponic media may be used as the main soil substitute in the system 100. The media is the main ingredient to pass the nutrients and maintain the right growth conditions for the plants. The system 100 integrates the use of LECA with hydroponics, making the system 100 more robust than felt or rock wool and other fibres. LECA is also cheaply available and can be easily handled without any hassle. LECA is more robust and lasts longer than the felt media. LECA doubles up as an effective VOC absorber and transports it to the plant roots for their degradation.

[0086] The system 100 is devoid of problems of soil-based mold, erosion and watering, as soil is not used. The plants (with their roots) with its media are in a sense suspended in air. The

media may be in contact with the water (with nutrients) while the roots absorb the water from the media. The plants system is a combination of hydroponic and aeroponics.

[0087] In various embodiments, LECA pebbles are used. LECA is known for their lightness, low thermal conductivity, high acoustic resistance, fire resistance, freezing-melting resistance. It is a good growing medium for plants. It has abilities to improve drainage, retain water for long durations, insulate roots during frost, and provide roots with increased oxygen levels promoting very vigorous growth. Along with the purification of air using plants is the disinfection that occurs at the disinfection module at the outlet of the system 100. The air exiting the system 100 is not only purified (cleaner) but also substantially disinfected (e.g., free of bacterial, free of virus, and/or free of mold).

[0088] The various modules in the system 100 are synchronised for effective airflow, ease of irrigation, and nurturing of plant growth. The interaction of air-water-plants is highly driven by the air flow dynamics. The air flow within the design is optimised to produce minimal pressure drop with maximum efficiency. The chamber 300 is shaped to ingest maximum air through the plants.

[0089] The system 100 is capable of circulating about 500 cubic metres of air every hour.

[0090] The system 100 can be used to stabilize TVOC/carbon dioxide levels in the indoor environment. Carbon dioxide moderation is an important parameter in green wall systems. Plants respire by absorbing carbon dioxide and giving out oxygen. In the system, this property of the plants is utilised to regulate the fresh air intake in the indoor space. The carbon dioxide sensor triggers the fan module in the system to moderate the levels of carbon dioxide in the given space.

[0091] Single-Sided Configuration

[0092] As mentioned, the system can be formed in terms of modules. To provide a single-sided configuration, one outer wall 400 is coupled to the chamber 300. Examples are shown in

FIG. 9A and FIG. 9B. In this example, the fan/disinfection module 800 is recessed to keep the footprint small and to dampen the noise of the fan. In this example, the electromechanical components are hidden from view, and the air flow within the system 100 is not disturbed.

[0093] The system 100 may be configured to operate at an optimized airflow in a range from 100 m^3 / $hour$ to about 1,000 m^3 / $hour$. As much as 80% of the materials for making the plant support modules, etc., may be selected from recyclable materials. That is, the present system 100 can be made by sustainable manufacturing.

[0094] Controller Module

[0095] To conserve energy, many office buildings operate the heating, ventilation, and air conditioning (HVAC) system only during the typical working hours. The indoor air can be stale and unhealthy when the HVAC is not in operation. In operation, the system 100 is useful for providing air purification benefits, e.g., in an indoor environment. The system 100 is particularly useful in enclosed indoor spaces, e.g., in high-rise office buildings where the windows are typically sealed for safety's sake or typically kept closed unless there is an emergency.

[0096] FIG. 10 is a schematic block diagram to illustrate the controller module 950 suitable for use with the present system 100. The system 100 includes a plant system 200. All the plants disposed on either of the outer walls 400 of the system 100 may be collectively referred to as the plant system 200. The system 100 includes the chamber/outer wall 300/400. Other modular components include: the planter module 600, the lighting module 700, the fan/disinfection module 800, and sensors 900. The plant system 200 may be a combination of hydroponic plants and aeroponic plants. In some examples, the plant system 200 includes green and leafy plants.

[0097] In some examples, a plant may be disposed in a plant support module 600 with some media (e.g., soil). In some examples, soil-less media may be used in the plant holder module

600. Examples of the media include but are not limited to soil, lightweight expanded clay aggregate (LECA) pebbles, etc.

[0098] The system 100 may be configured with a demand-based active controller module 950. The system 100 may be implemented as an Internet-of-Things (IoT) solution. The system 100 may include anti-bacterial and anti-viral properties. The proposed system 100 may be compatible with IAQ trends in the management of carbon dioxide, TVOC, PM, temperature-relative humidity (T-RH), and noise pollution.

[0099] The system 100 may be configured to complement the HVAC system and can be retrofitted easily into various indoor environments. The system 100 can be built using tropical/leaf-based plants. This system 100 can be "smart"-enabled by indoor air quality (IAQ) sensors (Singapore Standards 554: 2016 – Code of Practice for Indoor Air Quality for Air-conditioned Buildings) that drive its fans based on the quality of indoor air. The system 100 may be configured to integrate with the carbon dioxide sensors readings with the fan speed control (using the fan coil unit of the respective fans) to control the amount of fresh air inside, thereby providing energy savings. The system 100 was equipped with the lighting module 700 and an automated irrigation system (watering system). A prototype of the system 100 demonstrated that the system 100 required relatively little to no maintenance over a period of months.

[00100] Prototypes

[00101] FIG. 11 and FIG. 12 are the front view and the side view (with panels removed) of prototypes of the present system 100. The system 100 may be said to provide an active green wall as air flowing past the plant system and flowing pas the disinfection module actively "cleans" the air.

[00102] FIG. 13 is a front view of another prototype and FIG. 14 is a side view of the same. The prototype was fitted with ultra violet light (more specifically, UV-C light at around 275 nm) as part of the disinfection module.

[00103] The internals partitions were made using stainless steel to avoid corrosion and to increase the strength, durability and recyclability of parts. Externally-disposed parts were manufactured out of wood and matching panels to suit the interiors of the room. The system comes with maximum aesthetic customization and recyclable materials. The plant holders were the only ones made of ABS plastic and claimed to have a shelf life of more than 10 years.

[00104] Air (e.g., "dirty" air) essentially enters the system 100 primarily or exclusively through the plants positioned by the plant holder module 600. As used herein, the term "dirty air", "air", etc., may be interchangeably used to refer to unpurified air that contains pollutants. The air (after being "pre-purified" by the plants) flows generally from the upper end (top 111) of the outer channel 414 to the lower end (base 112) of the outer channel 414. The air then enters the tank cavity 324 through the slit corresponding to the tank inlet 322 / outer channel outlet 416. The direction of the airflow is inverted (redirected or reversed 180°) at the water surface of the water in the tank cavity324. The air flows from the lower end (base 112) of the shaft channel 344. The reversal in airflow direction at the surface of water further purifies the air (e.g. remove particulate matter, etc.), thereby acting like a simplified mechanical cyclone. The purified air then flows towards the upper end (top 111) of the shaft channel 344 and is further disinfected by the disinfected module before being sent outside of the system 100. In effect, the system 100 enables a multi-stage 'purification' for each intake or each volume of air drawn into the system 100.

[00105] In various embodiments of the present disclosure, the proposed system includes a chamber and an outer wall. The chamber includes a tank and a shaft. The tank is disposed at a base of the system. The tank defines a tank cavity with a tank inlet and a tank outlet. The shaft

includes a shaft wall. The shaft wall defines a shaft channel. The shaft channel extends from the tank cavity along a reference axis towards a top of the system. The outer wall is coupled to the chamber to cooperatively define an outer channel between the outer wall and an exterior surface of the shaft wall. The shaft wall is inclined relative to the reference axis to define an increasingly smaller cross-sectional area for the outer channel towards the tank cavity and to correspondingly define an increasingly smaller cross-sectional area for the shaft channel away from the tank cavity.

[00106] The outer channel may be characterized by a smaller cross-sectional area at the tank inlet than the cross-sectional area of the shaft channel at a tank outlet.

[00107] The shaft channel may be characterized by a smaller cross-sectional area at a shaft outlet than at a shaft inlet. The shaft outlet may be defined at the top of the system. The shaft inlet may interface with a tank outlet at the tank.

[00108] The outer wall may include external openings to receive air flow into the outer channel via the external openings.

[00109] The system may further include a fan/disinfection module. The fan/disinfection module may be operable to draw air from an environment external to the system across the outer wall.

[00110] The fan/disinfection module may be operable to effect a reversal of a direction of the air at the tank cavity before the air is drawn into the shaft channel.

[00111] The system may further include one or more fans, one or more sensors, and a controller module. The one or more fans may be disposed in the shaft channel proximal to the base of the system. The one or more sensors may be deposed at the system. The controller module may be configured to controllably adjust a fan speed of the one or more fans in response to data obtained from the sensors.

[00112] The one or more fans may be distributed along a length of the system in the shaft channel.

[00113] The system may include one or more disinfection module. The one or more disinfection module may be one or a combination of any two or more selected from the following: ultra-violet radiation, temperature, plasma, silver ions, ozone, and titanium oxide coatings.

[00114] The system may further include a light disposed at an overhang extending above the outer wall.

[00115] The system may further include a fan module. The fan module may be disposed in the first channel. The fan module may be configured to draw air outside when in operation via the first channel.

[00116] The fan module may further include a disinfection module.

[00117] The system may further include a plurality of plant support modules. Each of the plurality of plant support modules may include a lower section and an upper section. The upper section may define a plurality of vents. The plurality of vents may provide for air flow in various different directions in the outer channel.

[00118] The system may further include a plant system. The plant system may include one or more plant disposed in a respective plant support module.

[00119] The system in operation may be configured to form an airflow path from an environment external of the system, through the outer wall, downward in the outer channel, via the tank cavity, and upward along the shaft channel, and in which the airflow path exits the system via the shaft outlet at the top of the system.

[00120] The airflow path may be formed at least in part by a fan disposed in the shaft channel. The fan may be operable to direct air upwards.

[00121] The airflow path may undergo reversal in direction upon interfacing with water in the tank cavity.

[00122] All examples described herein, whether of apparatus, methods, materials, or products, are presented for the purpose of illustration and to aid understanding, and are not intended to be limiting or exhaustive. Modifications may be made by one of ordinary skill in the art without departing from the scope of the claimed invention.

CLAIMS

1. A system comprising:

a chamber, the chamber including:

a tank, the tank being disposed at a base of the system, the tank defining a tank cavity with a tank inlet and a tank outlet; and

a shaft including a shaft wall, the shaft wall defining a shaft channel, the shaft channel extending from the tank cavity along a reference axis towards a top of the system; and

an outer wall, the outer wall being coupled to the chamber to cooperatively define an outer channel between the outer wall and an exterior surface of the shaft wall,

wherein the shaft wall is inclined relative to the reference axis to define an increasingly smaller cross-sectional area for the outer channel towards the tank cavity and to correspondingly define an increasingly smaller cross-sectional area for the shaft channel away from the tank cavity.

2. The system as recited in claim 1, wherein the outer channel is characterized by a smaller cross-sectional area at the tank inlet than the cross-sectional area of the shaft channel at a tank outlet.

3. The system as recited in claim 1 or claim 2, wherein the shaft channel is characterized by a smaller cross-sectional area at a shaft outlet than at a shaft inlet, the shaft outlet being defined at the top of the system, and wherein the shaft inlet interfaces with a tank outlet at the tank.

4. The system as recited in any one of claims 1 to 3, wherein the the outer wall comprises external openings to receive air flow into the outer channel via the external openings.

5. The system as recited in any one of claims 1 to 4, further comprising: a fan/disinfection module, the fan/disinfection module being operable to draw air from an environment external to the system across the outer wall.

6. The system as recited in claim 5, wherein the fan/disinfection module is operable to effect a reversal of a direction of the air at the tank cavity before the air is drawn into the shaft channel.

7. The system as recited in any one of claims 1 to 6, further comprising:
one or more fans, the one or more fans being disposed in the shaft channel proximal to the base of the system;
one or more sensors, the one or more sensors being deposed at the system; and
a controller module, the controller module being configured to controllably adjust a fan speed of the one or more fans in response to data obtained from the sensors.

8. The system as recited in claim 7, wherein the one or more fans are distributed along a length of the system in the shaft channel.

9. The system as recited in claim 7, further comprising:
one or more disinfection module, wherein the one or more disinfection module is one or a combination of any two or more selected from the following: ultra-violet radiation, temperature, plasma, silver ions, ozone, and titanium oxide coatings.

10. The system as recited in claim 7 or claim 8, further comprising:

a light disposed at an overhang extending above the outer wall.

11. The system as recited in claim 1, further comprising:

a fan module, the fan module disposed in the first channel, the fan module is configured to draw air outside when in operation via the first channel.

12. The system as recited in claim 1 and 6, wherein the fan module further comprising a disinfection module.

13. The system as recited in any one of claims 1 to 12, further comprising a plurality of plant support modules, each of the plurality of plant support modules including:

a lower section; and

an upper section, wherein the upper section defines a plurality of vents, the plurality of vents providing for air flow in various different directions in the outer channel.

14. The system as recited in any one of claims 1 to 13, further comprising a plant system, wherein the plant system includes one or more plant disposed in a respective plant support module.

15. The system as recited in any one of claims 1 to 14, wherein the system in operation is configured to form an airflow path from an environment external of the system, through the outer wall, downward in the outer channel, via the tank cavity, and upward along

the shaft channel, and wherein the airflow path exits the system via the shaft outlet at the top of the system.

16. The system as recited in claim 15, wherein the airflow path is formed at least in part by a fan disposed in the shaft channel, and wherein the fan is operable to direct air upwards.

17. The system as recited in claim 15, wherein the airflow path undergoes a reversal in direction upon interfacing with water in the tank cavity.

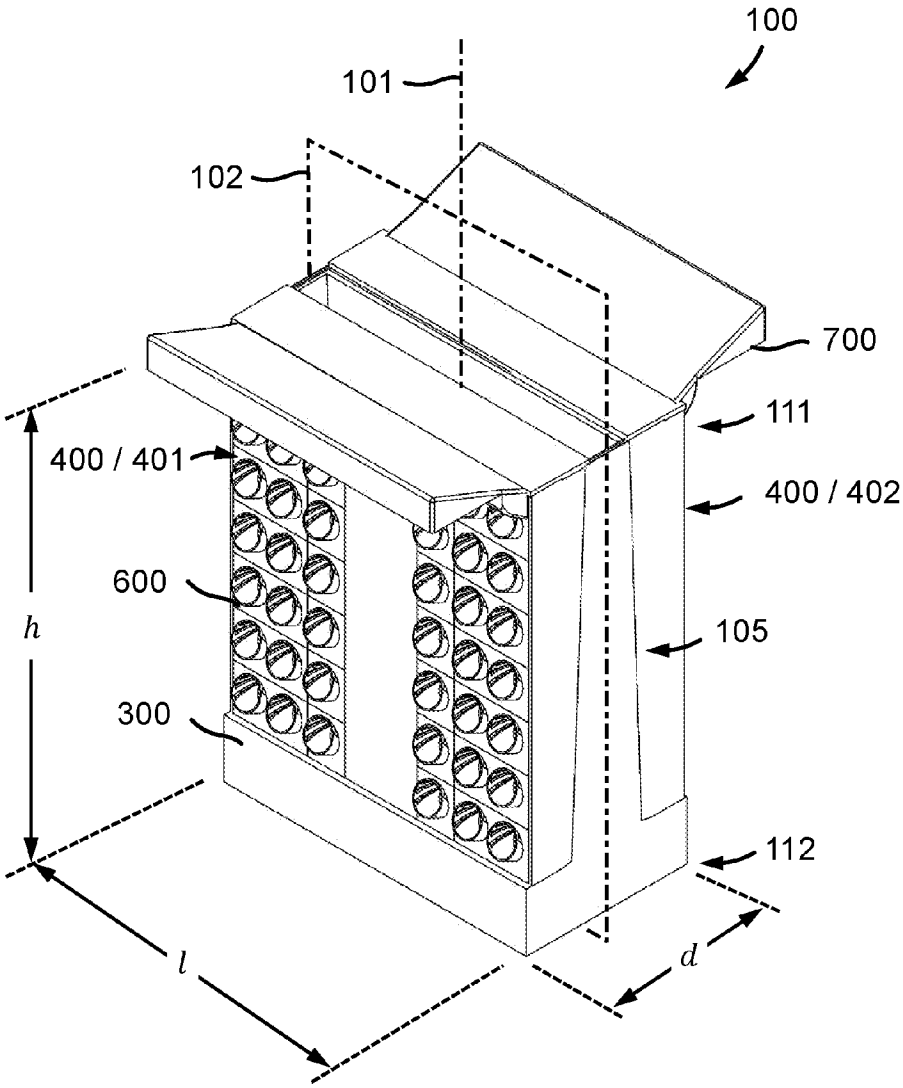


FIG. 1

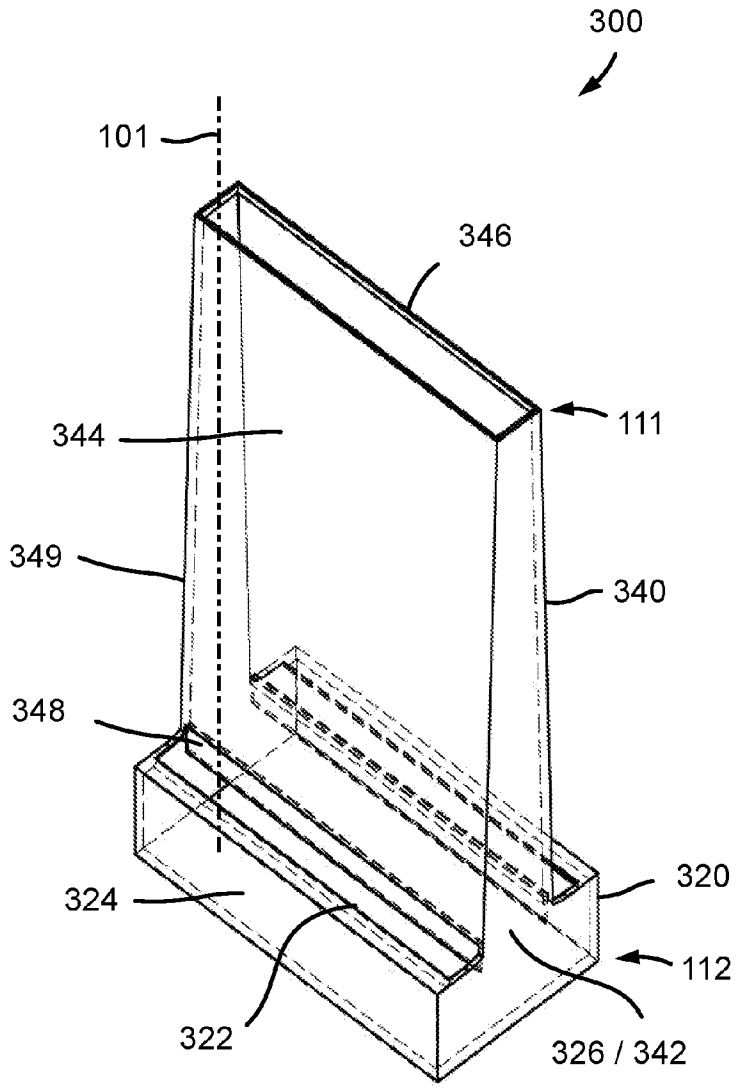


FIG. 2

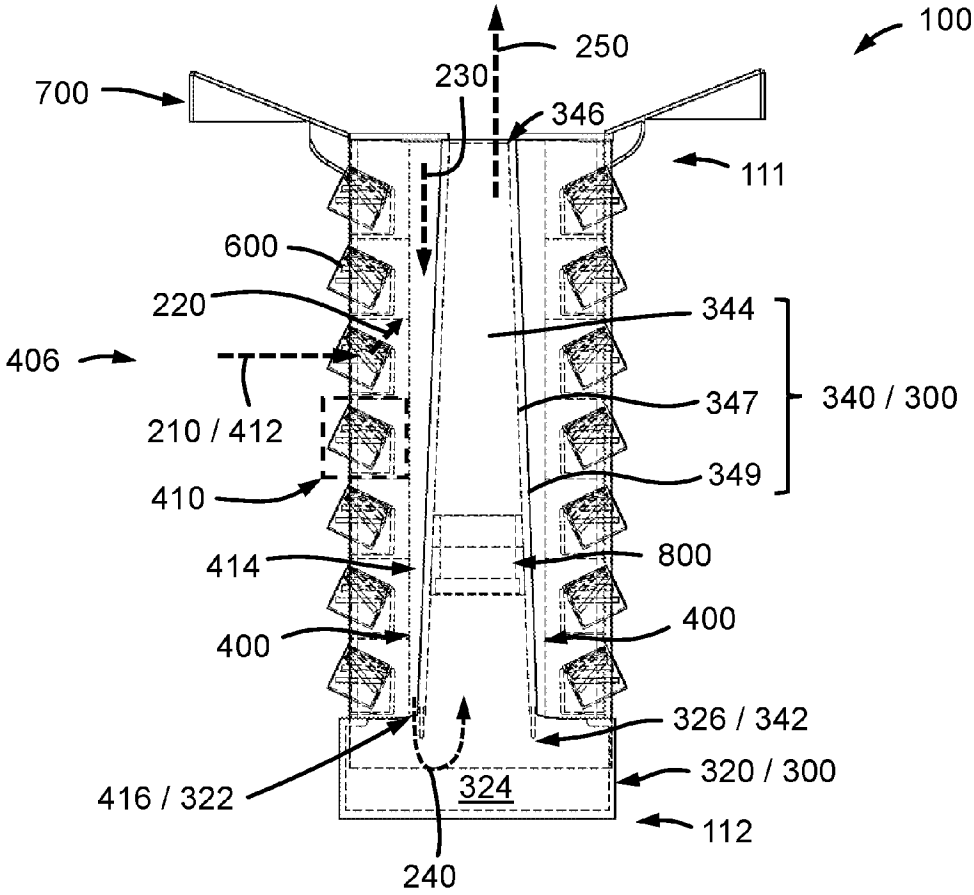

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320 / 300
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FIG. 3A

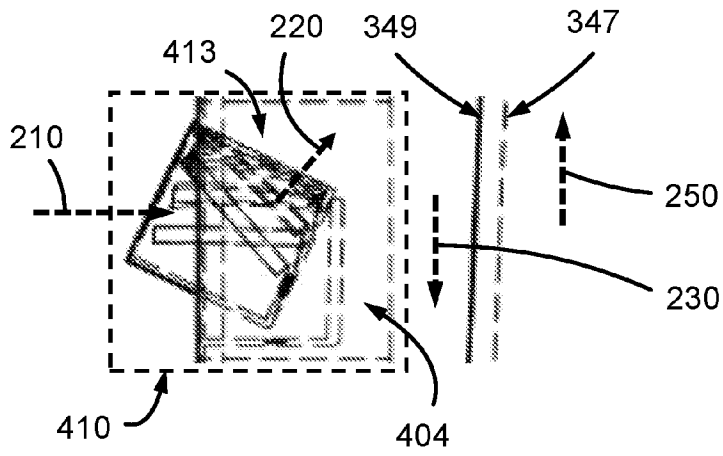

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FIG. 3B

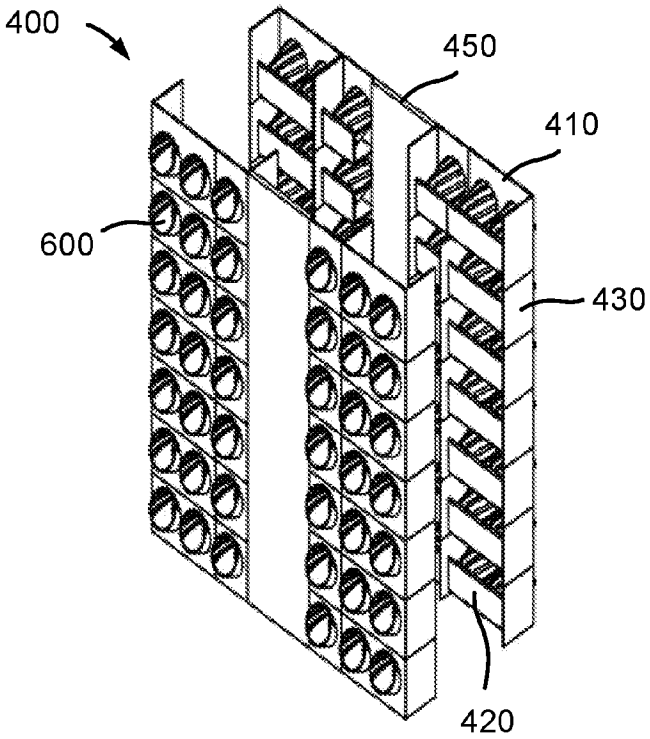


FIG. 4A

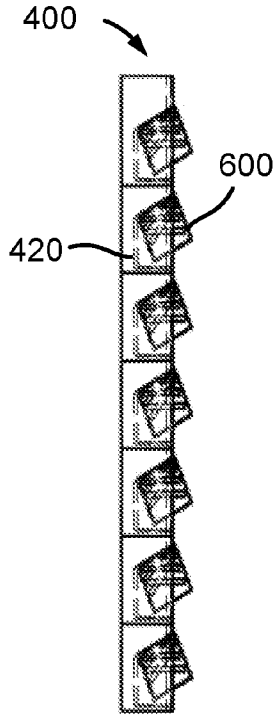


FIG. 4B

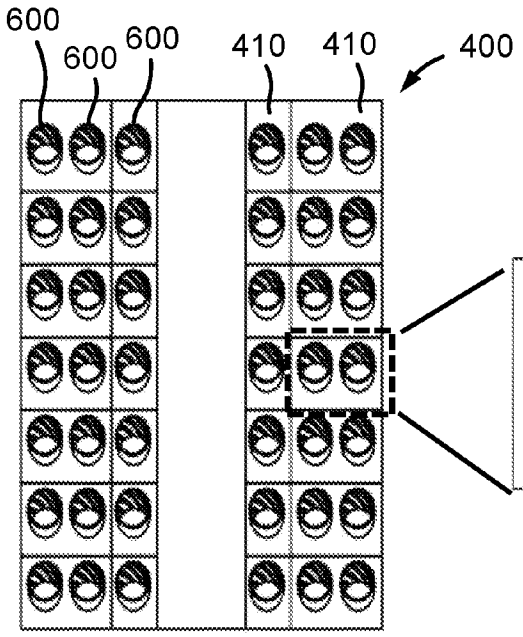


FIG. 4C

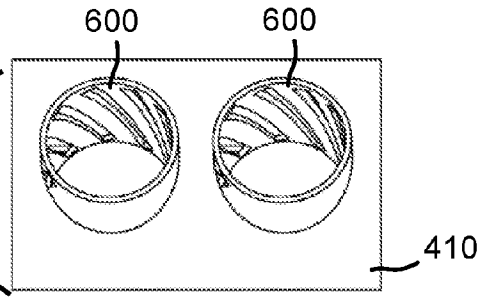


FIG. 5A

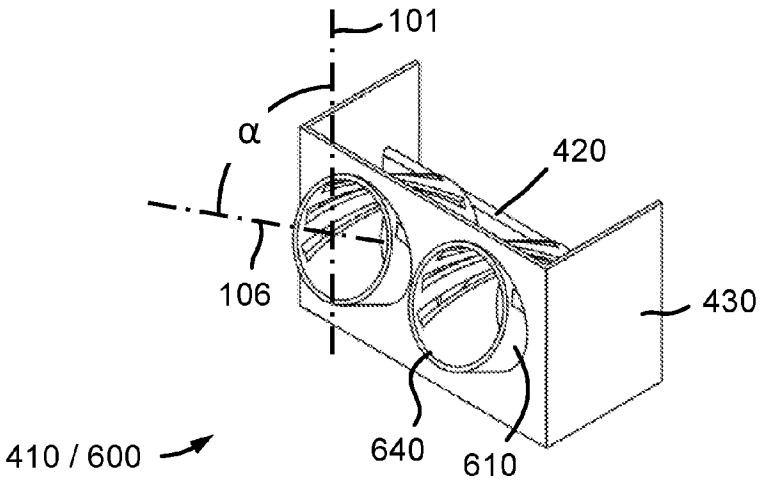


FIG. 5B

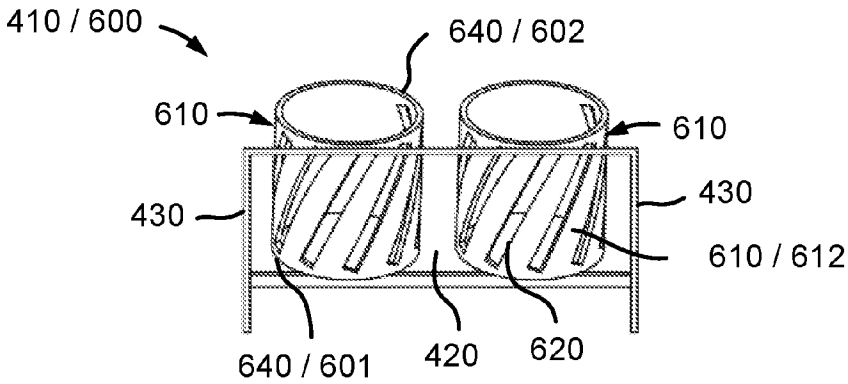


FIG. 5C

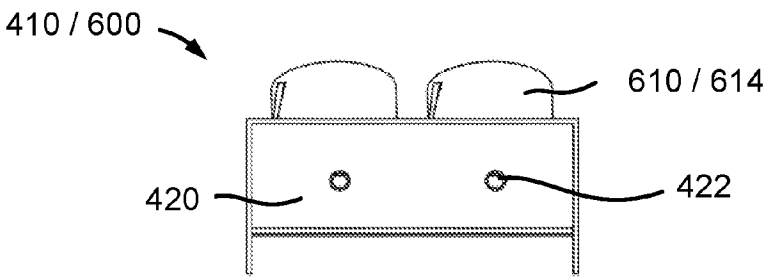


FIG. 5D

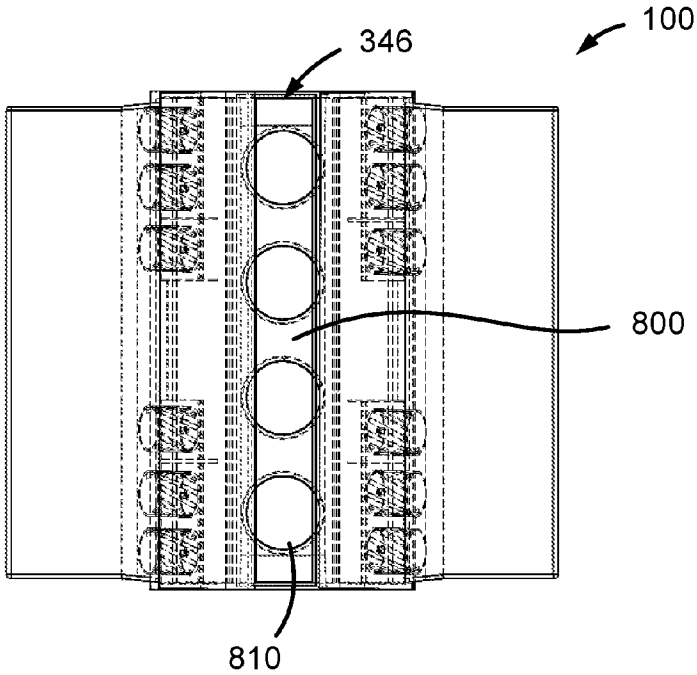


FIG. 6A

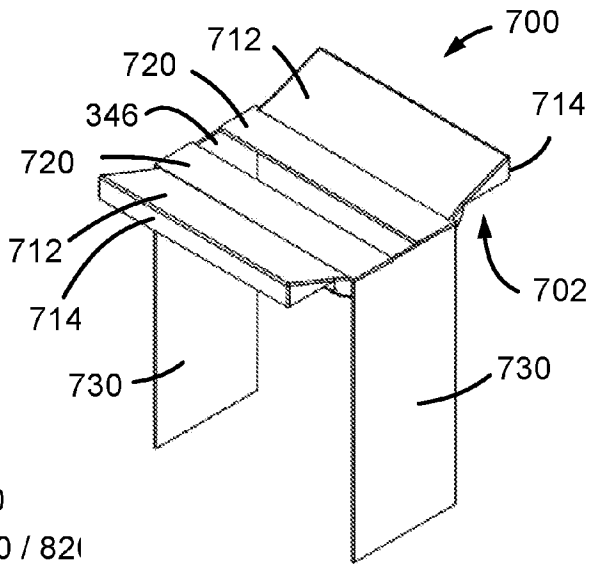


FIG. 6B

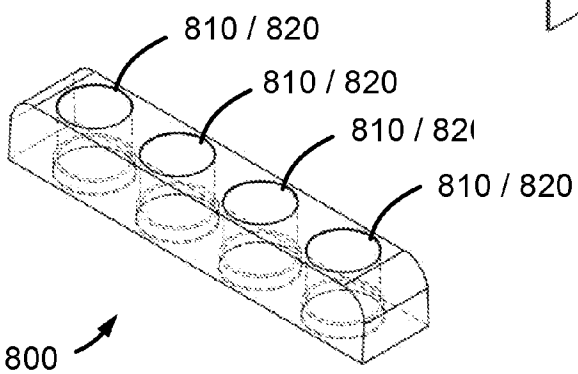


FIG. 7

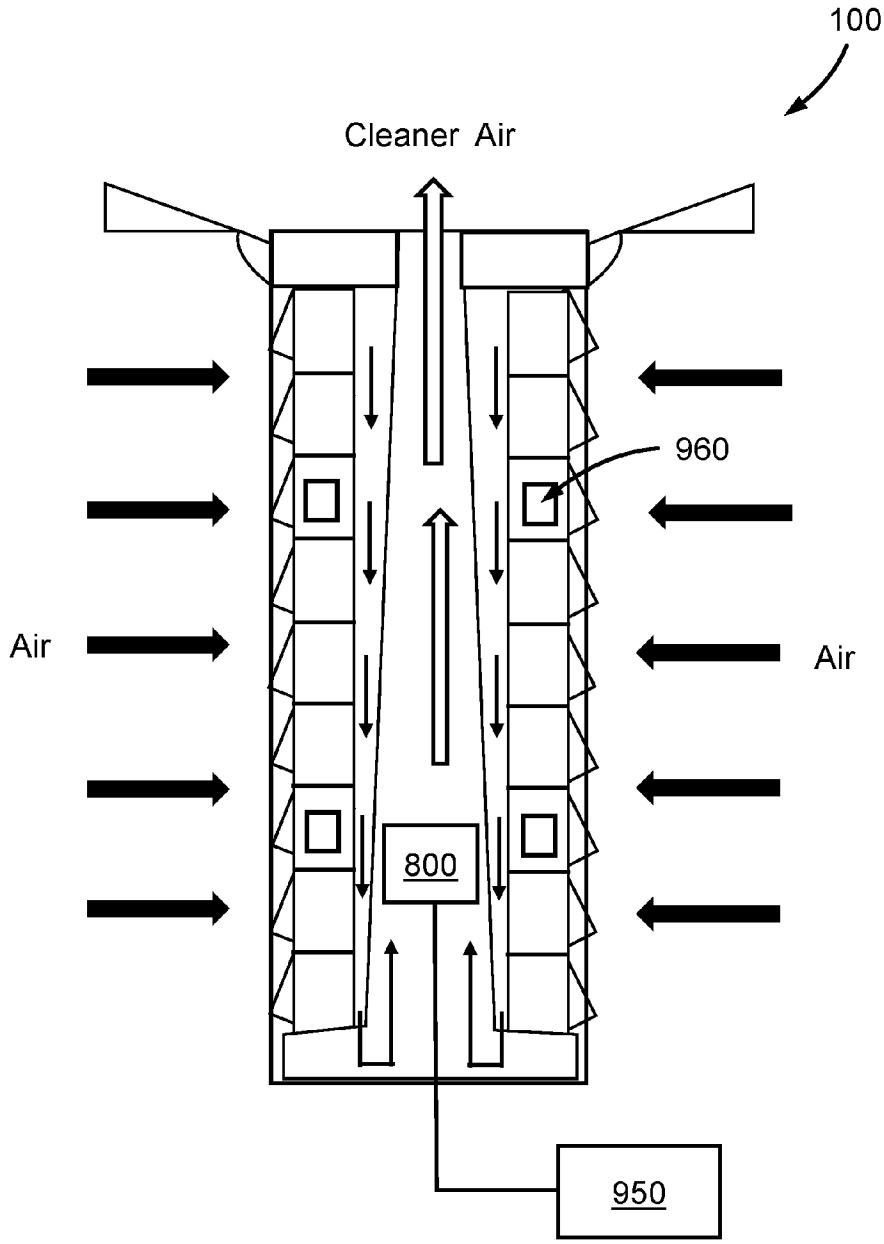


FIG. 8

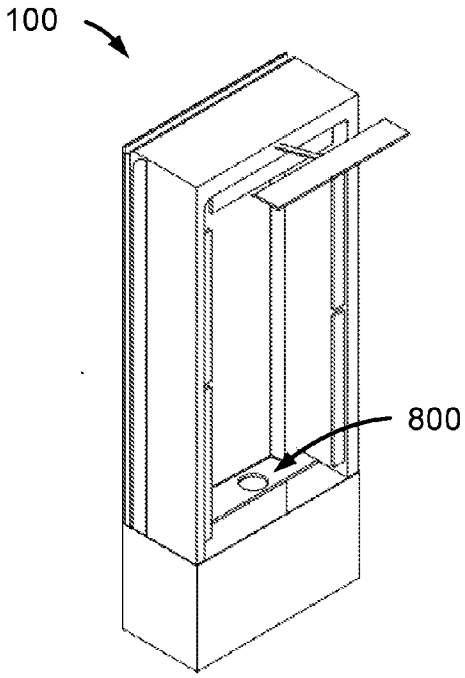


FIG. 9A

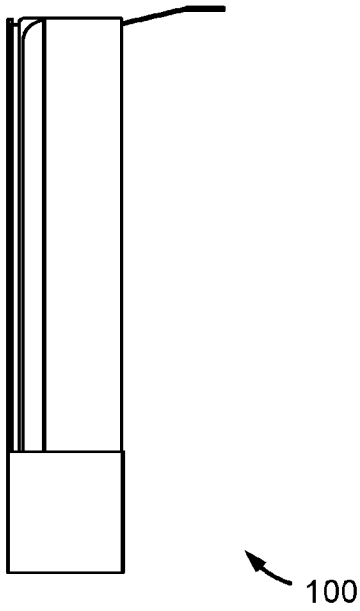


FIG. 9B

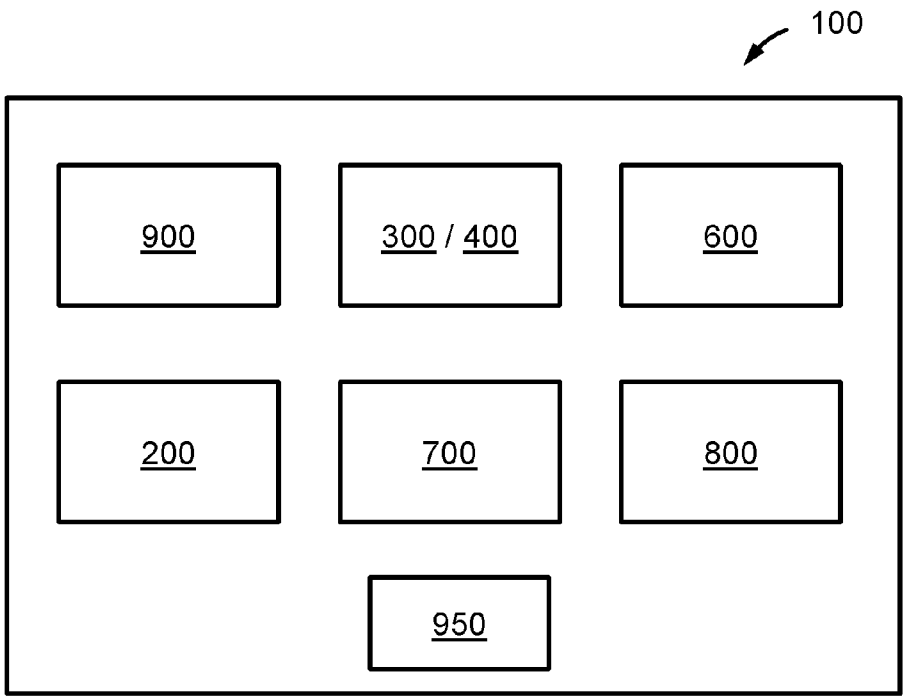


FIG. 10

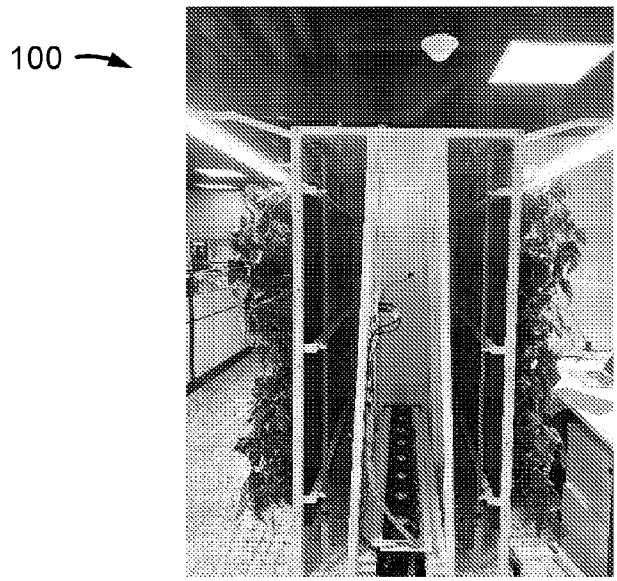


FIG. 11

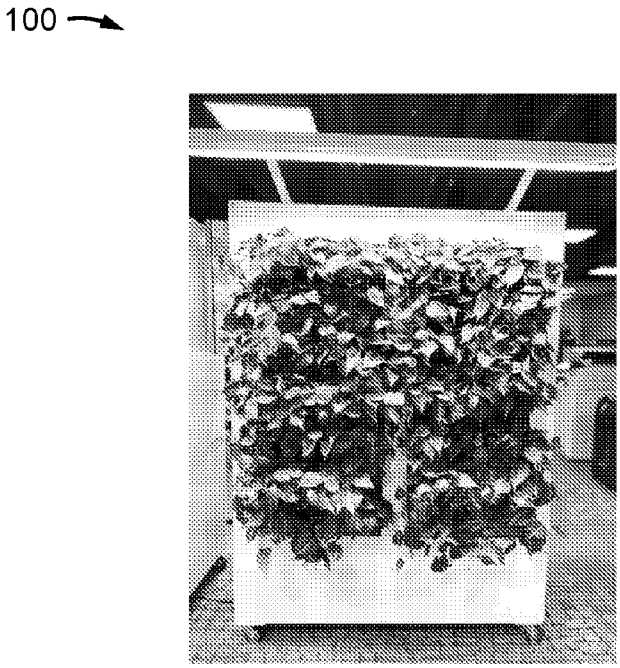


FIG. 12

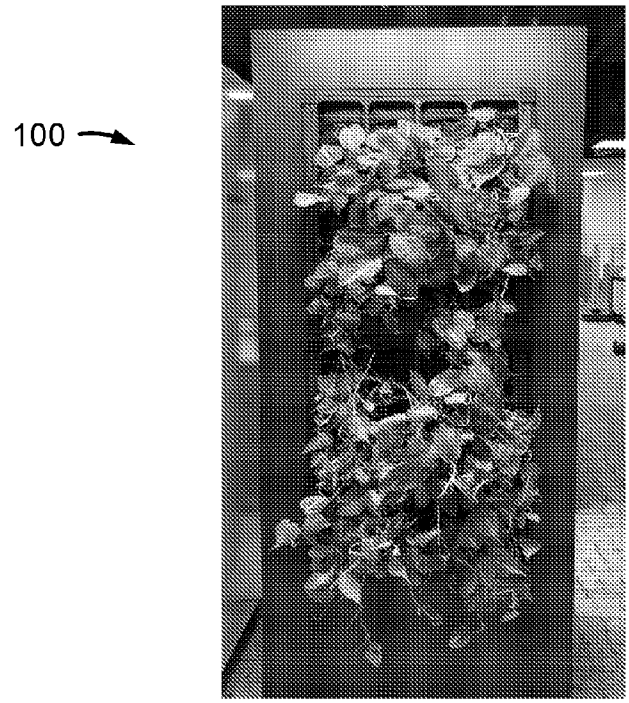


FIG. 13



FIG. 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG2023/050852

A. CLASSIFICATION OF SUBJECT MATTER

A01G 9/02 (2018.01)

According to International Patent Classification (IPC)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A01G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

FAMPAT: Green wall, active living wall, vertical wall, plant, tank, chamber, cavity, shaft, channel, air flow, and related terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013/0160363 A1 (WHITNEY S. J. & GIACOMANTONIO P. J.) 27 June 2013 Paragraphs [0056]-[0060] and Figure 9	1-17
A	US 2003/0224507 A1 (DARLINGTON A. B.) 4 December 2003 Paragraph [0016] and Figure 1	1-17
A	RAKHSHANDEHROO M. ET AL., Living Wall (Vertical Greening): Benefits and Threats. *Applied Mechanics and Materials*, 31 May 2015, Vol. 747, pages 16-19 [Retrieved on 2024-02-29] <DOI: DOI.ORG/10.4028/WWW.SCIENTIFIC.NET/AMM.747.16> Figure 4	-

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

*Special categories of cited documents:

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"D" document cited by the applicant in the international application

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29/02/2024 *(day/month/year)*	01/03/2024 *(day/month/year)*
Name and mailing address of the ISA/SG	Authorized officer
Intellectual Property Office of Singapore 1 Paya Lebar Link, #11-03 PLQ 1, Paya Lebar Quarter Singapore 408533 Email: pct@ipos.gov.sg	Kenneth Tan (Dr) IPOS Customer Service Tel. No.: (+65) 6339 8616

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SG2023/050852

Note: This Annex lists known patent family members relating to the patent documents cited in this International Search Report. This Authority is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013/0160363 A1	27/06/2013	NONE	
US 2003/0224507 A1	04/12/2003	NONE	