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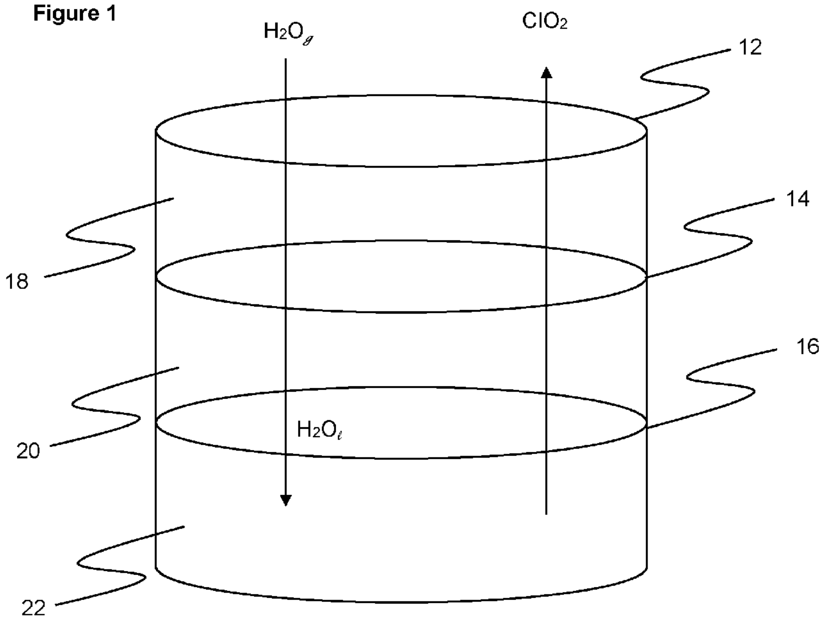
(54) Title: SUSTAINED RELEASE CHLORINE DIOXIDE ANTISEPSIS

Figure 1



(57) Abstract: Processes, systems and devices are provided that facilitate the sustained, metered release of chlorine dioxide gas, using reactions that make use of water vapor while involving the control of the relative humidity within a reaction container. In this way, the rate of chlorine dioxide gas generation is made to be selectively independent of external ambient relative humidity levels, while ambient water vapor continues to be available as a source of water for sustaining long term ClO_2 gas generation.

[Continued on next page]

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SUSTAINED RELEASE CHLORINE DIOXIDE ANTISEPSIS

FIELD

[0001] The invention is in the field of chlorine antiseptic and odor abatement chemistry, and devices for the metered generation and use of chlorine antiseptics, including chlorine dioxide gas.

BACKGROUND

[0002] Various forms of chlorine have seen longstanding use as antiseptics. U.S. Patent No. 1,668,371, for example describes a chlorine dioxide generating apparatus with a disclosed utility in providing chlorine dioxide antiseptic as a therapeutic agent in the context of certain respiratory diseases. The protective effect of low-concentrations of chlorine dioxide gas against viral pathogens, such as influenza A virus, has continued to attract academic attention (see Ogata & Shibata, 2008). Chlorine dioxide is a distinct species of chlorine antiseptic, being a paramagnetic radical with high water solubility, even in cold water, which does not hydrolyze in aqueous solutions (with a solubility in water of 8 g/L at 20°C as a dissolved gas in solution). Unlike chlorine, chlorine dioxide does not chlorinate organic compounds to form potentially carcinogenic organochloride compounds, such as trihalomethanes.

[0003] Although chlorine species have recognized utility as antiseptics, there is also a recognition that chlorine can be dangerous to human health, and indeed can be weaponized. In the United States, the Environmental Protection Agency and the Occupational Safety and Health Administration have accordingly established regulatory limits for exposure to chlorine dioxide gas, based on the recognition that exposure to even sub ppm levels may result in discomfort and irritation (the conversion factor for chlorine dioxide in air at 20°C and 101.3 kPa is 1 ppm = 2.8 mg/m^3).

[0004] The establishment of regulatory exposure limits is in part a reflection of the fact that chlorine dioxide is in widespread industrial use, typically as a sanitizer or bleaching agent. Due to the inherent instability of ClO_2, which is capable of explosive gas phase decomposition into chlorine and oxygen, it is usually generated as needed. This is typically accomplished by mixing metered amounts of reactants from distinct reservoirs, for example by the oxidation of a chlorite (ClO_2^-), typically sodium chlorite ($NaClO_2$), which may be accomplished with chlorine, an acid (such as hydrochloric, or sulphuric acid) or hydrogen peroxide. Alternative processes involve the reduction of a chlorate (ClO_3^-), typically potassium chlorate ($KClO_3$), for example with oxalic acid or in a strong acid solution with a suitable reducing agent such as methanol, hydrogen peroxide, hydrochloric acid or sulfur dioxide. Aqueous (dissolved gas) or gaseous chlorine dioxide may be produced by such processes, the melting point of ClO_2 being −59°C and the boiling point 11 °C.

[0005] In small scale processes (see US Patent Nos. 6,294,108 and 8,361,409) water required for the aqueous generation of chlorine dioxide may be provided in small aliquots, or by ambient water vapor. The presence of ambient water vapor is often expressed in percentage terms as “relative humidity” (RH), reflecting the relationship between the amount of water vapor present and the maximum amount that is physically possible at that temperature, i.e. the partial water vapor pressure in relation to the saturation pressure: $\% \text{ RH} = 100\% * (P_w / P_{ws})$; where: P_w = partial water vapor pressure; and, P_{ws} = water vapor saturation pressure. In chlorine dioxide generation processes that rely on ambient humidity, the ambient partial water vapor pressure may control the rate of ClO_2 gas generation, and this may accordingly deviate from a rate that would be preferred for purposes of effective sanitation or health outcomes.

SUMMARY

[0006] Processes, systems and devices are provided that facilitate the sustained, metered release of chlorine dioxide gas, using reactions that make use of water vapor while involving the control of the relative humidity within a reaction container. In this way, the rate of chlorine dioxide gas generation is made to be selectively independent of external ambient relative humidity levels, while ambient water vapor continues to be available as a source of water for sustaining long term ClO_2 gas generation.

[0007] A sustained chlorine dioxide gas generating system is provided that includes a chlorine dioxide gas generation (GG) subsystem or unit, comprising an activator (such as an acid or oxidative activator) and a chlorite or chlorate reactant (such as a solid metal chlorite or chlorate) in a GG container, which may be water vapor permeable and chlorine dioxide gas permeable. A relative humidity control (RHC) subsystem or unit is also provided, including a hygrostatic material that absorbs water vapor above an upper water vapor partial pressure and releases water vapor below a lower water vapor partial pressure. The RHC may be located in a container, for example a container that is water vapor permeable and chlorine dioxide gas permeable. A housing contains the GG subsystem and the RHC subsystem. The housing permits the ingress of water vapor at an ambient humidity, the RHC subsystem then modulates the water vapor partial pressure within the housing, and the housing permits the egress of a chlorine dioxide gas evolved from the GG subsystem by a ClO_2-gas-generating reaction between the activator and the reactant. In this way, the rate of the ClO_2-gas-generating reaction is modulated by the water vapor partial pressure within the housing.

[0008] In select embodiments, the activator may include one or more of: citric acid, phosphoric acid, acetic acid, adipic acid, boric acid, formic acid, glutaric acid, hydrochloric acid, lactic acid, maleic acid, mandelic acid, malic acid, sulfuric acid, sodium persulfate, sodium bisulphate, phosphoric anhydride, sulfuric anhydride, maleic anhydride, calcium chloride, magnesium chloride, magnesium nitrate, lithium chloride, magnesium sulfate, aluminum sulfate, sodium acid sulfate, sodium dihydrogen phosphate, potassium acid sulfate, potassium dihydrogen phosphate, tartaric acid or a mixtures thereof.

[0009] In select embodiments, the chlorite reactant may include a solid metal chlorite, such as: sodium chlorite, calcium chlorite, barium chlorite, magnesium chlorite, potassium chlorite, an alkali metal chlorite, an alkaline earth metal chlorite, or a mixture thereof.

[0010] The hygrostatic material may include one or more of: sodium chloride, calcium chloride, sodium nitrite, potassium nitrite, ammonium nitrate, ammonium carbonate or a mixture thereof. Alternatively, the hygrostatic material may include:

sucrose, fructose, glucose, galactose, sorbitol, xylitol, mannitol, citric acid, maleic acid, malic acid, succinic acid, sodium citrate, sodium malate, sodium tartrate or a mixture thereof. In some embodiments, the hygroscopic material may be made from a gel forming material.

[0011] The gas generating (GG) subsystem may include a deliquescent material, such as: aluminum chloride, ammonium chloride, ammonium sulphate, anhydrous sodium sulfate, barium chloride, calcium chloride, calcium nitrate, calcium sulphate, lithium chloride, magnesium acetate, magnesium chloride, magnesium nitrate, potassium bromide, potassium carbonate, potassium chloride, potassium sulphate, sodium carbonate, sodium chloride, sodium nitrite, sodium phosphate or a mixture thereof.

[0012] The GG container may be water resistant. Similarly, RHC container may be water resistant. Further, the housing that contains the GG subsystem and the RHC subsystem may also be water resistant.

[0013] Methods are disclosed for providing chlorine dioxide to a space, by operating the systems disclosed herein in the space. The space may for example be humidified by operating a humidifier in the space to increase the ambient humidity.

[0014] Control systems are provided for use with distributed chlorine dioxide gas generating systems in a defined space. For example, a chlorine dioxide gas generation (GG) subsystems are provided that include an activator, a chlorite or chlorate reactant, and a metered aqueous reaction medium release mechanism. A reaction rate control (RRC) subsystem may be provided, comprising one or more chlorine dioxide gas sensors distributed in the defined space, communicating chlorine dioxide gas concentration information to the GG subsystem. A control system may be further provided, modulating the metered release of an aqueous GG reaction medium from the metered aqueous reaction medium release mechanism in response the chlorine dioxide gas concentration information provided by the RRC subsystem, wherein the control system thereby modulates desired concentrations of chlorine dioxide gas in the space. Humidity control systems may be provided in the defined space, the humidity control system comprising humidity sensors distributed in the defined space, communicating humidity information to the control system modulating the metered release of the aqueous GG reaction medium, wherein the control system modulates the metered release of the aqueous GG reaction medium based on the humidity information. The control system may accordingly be configured to maintain a concentration of chlorine dioxide gas in the space that is at or below a ClO_2 gas maximum threshold, for example 0.1 or 0.2 or 0.3 or 0.4 or 0.5 or 0.6 or 0.7 or 0.8 or 0.9 or 1.0 ppm. The control system may similarly be configured to maintain a concentration of chlorine dioxide gas in the space that is at or above a ClO_2 gas minimum threshold, such as 0.009, 0.01 or 0.02 or 0.03 or 0.04 or 0.05 or 0.06 or 0.07 or 0.08 or 0.09 ppm. One or more actuatable chlorine dioxide gas absorbers may be provided, distributed in the defined space, the absorbers being actuatable by the control system to reduce the level of chlorine dioxide gas in the space when the concentration of the chlorine dioxide gas is at or above the ClO_2 gas maximum threshold. The chlorine dioxide gas sensors may for example be portable and/or wearable. The control system may include a clock, and the control system may be configured to temporally modulate the concentration of chlorine dioxide gas in the space. The control system may include manual controls, for adjusting the desired concentration of chlorine dioxide gas in the space, and may further include a locking mechanism to restrict access to the system.

[0015] In some embodiments, a sustained chlorine-dioxide-gas-generating personnel covering system is provided. The personnel covering may include a chlorine dioxide gas generation (GG) subsystem, comprising an activator and a chlorite or chlorate reactant in a GG container that is water vapor permeable and chlorine dioxide gas permeable. An anthropogenic humidity control (AHC) subsystem may be provided, comprising a desiccant that absorbs water vapor, in an AHC unit that is water vapor permeable and chlorine dioxide gas permeable, the AHC unit enveloping the GG subsystem. A personnel covering may be provided configured to support the GG subsystem enveloped by the AHC unit, the personnel covering being configured to cover a body portion of a wearer while permitting air comprising anthropogenic humidity generated by the wearer to contact the AHC subsystem, the AHC subsystem being configured to modulate water vapor partial pressure within the GG subsystem, the AHC unit being configured to permit the egress of a chlorine dioxide gas evolved from the GG subsystem by a ClO_2 reaction between the activator and the reactant, where the ClO_2 reaction is modulated by the water vapor partial pressure within the GG subsystem. The personnel covering system may include a facemask configured to substantially cover the wearer's mouth and/or nose and to filter air inhaled and/or exhaled by the wearer while permitting exhaled air comprising exhaled humidity to contact the AHC subsystem. The personnel covering may be configured to removably support the GG subsystem enveloped by the AHC unit, the GG subsystem and/or AHC subsystem being removable from the personnel covering. The GG subsystem may for example be releasably enveloped by the AHC unit, the GG subsystem being removable from the AHC unit. The personnel covering system may further include a chlorine dioxide abatement system configured to dissipate chlorine dioxide, such as an abatement system that includes metallic copper.

[0016] Methods and systems disclosed herein may be adapted to a wide variety of uses, such as odor control, inhibition of growth or distribution of a microbial pathogen (such as a virus, a bacteria, a fungus, a protozoan, a coronavirus, an influenza virus or SARS-CoV-2).

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] **Figure 1** is a schematic illustration of a cylindrical chlorine dioxide generator.

[0018] **Figure 2** is a schematic illustration of an alternative flexible chlorine dioxide generator, in (**A**) cross section and (**B**) plan views.

DETAILED DESCRIPTION

[0019] In one aspect, systems disclosed herein may be used for the prophylactic prevention of microbial infection caused by fomite transmission, or direct or indirect pathogen transmission of microbial pathogens. Prophylaxis of this kind may for example be achieved by relatively low chlorine dioxide concentrations (see Boone

& Gerba, 2007; Miura & Shibata, 2010; Ogata & Shibata, 2008; Morino et al., 2011), for example below 0.1 ppm, such as in the range of 0.01 ppmv to 0.2 ppmv, for example of at least 0.05 ppmv (0.14 mg/m^3). In alternative embodiments, devices and systems disclosed herein may be used to generate and maintain a concentration of chlorine dioxide gas in a given volume over a relatively wide range, for example of from between about 0.005 to about 10.0 ppm, or from about 0.005 to about 1.0 ppm. The sustained release chlorine dioxide dispensing devices disclosed herein may accordingly be situated within a space to be disinfected having a known approximate volume, the device being selected and sized so as to provide a desired concentration of chlorine dioxide gas over a desired period of time.

[0020] Referring to **Figure 1**, a device is disclosed that provides a sustained chlorine dioxide gas generation system, which includes a chlorine dioxide gas generation (GG) subsystem made up of adjoining compartments **20** and **22**. Compartment **20** contains an activator, such as a sold acid, for example citric acid, while compartment **22** contains a chlorite or chlorate reactant, such as a solid metal chlorite, such as sodium chlorite. In the illustrated embodiment, compartments **20** and **22** are separated by membrane **16** that separates the dry reactants while permitting the passage of dissolved reactants to mediate a chlorine dioxide generating reaction. In the illustrated embodiment, the external circumferential and bottom walls of the housing are substantially impermeable, so that ambient water is permitted to enter the housing through a relative humidity control (RHC) subsystem **18**, positioned on top of the GG subsystem. The RHC subsystem thereby modulates the relative humidity within the GG subsystem, permitting the flow of water vapor (down arrow, H_2O_g) into the housing through external barrier membrane **12**, which is water vapor permeable and chlorine dioxide gas permeable, and may be water resistant. Internal barrier separator **14** segregates the RHC subsystem from the GG subsystem. The relative permeability of barriers **12** and **14** may be selected so that barrier **14** is more permissive of water vapour passage than barrier **12**, so that the RHC unit thereby more efficiently modulates the relative humidity of the GG subsystem, while affording ingress of ambient water vapour (denoted in **Figure 1** as H_2O_g), that then provides liquid water (denoted in **Figure 1** as H_2O_ℓ) to mediate the chlorine dioxide generating reaction within the GG subsystem.

[0021] The relative humidity control (RHC) subsystem, may include a hygrostatic material that absorbs water vapor above an upper water vapor partial pressure and releases water vapor below a lower water vapor partial pressure. In effect, the RHC functions as a hygrostat, providing humidity control via a two-way humectant mechanism, mediated by compositions such as glycerin water solutions or saturated salt solutions, which are capable of both capturing and releasing moisture, allowing for the relative humidity within the GG subsystem to be increased or decreased to a desired relative humidity compared to the external ambient humidity. The hygrostatic material may capture and release moisture by a variety of mechanisms, such as absorption, adsorption, and evaporation. In the illustrated embodiment of **Figure 1**, the exterior circumferential walls of the RHC subsystem are substantially impermeable, while the barrier **12** is water vapor permeable and chlorine dioxide gas permeable, and may be water resistant. The RHC subsystem is thereby provided in a container that is water resistant, water vapor permeable and chlorine dioxide gas permeable.

[0022] As illustrated in **Figure 1**, The GG subsystem and the RHC subsystem are together maintained in a housing formed by the exterior circumferential and bottom walls thereof, coupled to exterior barrier **12**. The housing provides a water-resistant and water-vapor-permeable environment for the GG subsystem and the RHC subsystem, permitting the ingress of water vapor, for example at an ambient temperature and humidity. The RHC subsystem then modulates the water vapor partial pressure within the housing, which in turn regulate the rate of chlorine dioxide gas generation, and the housing then permits the egress of chlorine dioxide gas evolved from the GG subsystem. In an alternative embodiment, a second RHC subsystem may for example be provided on the bottom of the housing, permitting gas flows to pass in and out of the unit through both ends. A fan may for example also be provided, to mediate gas flows through the unit. Fans may for example be made to be responsive to controls, automated or manual, for example to increase gas flows so as to increase ClO_2 generation by the unit.

[0023] **Figure 2 A** and **B** illustrate an alternative embodiment, showing a cross section **A** and a plan view **B** of a flexible packet in which multiple GG subsystems are formed by compartments **28** and **32**, separated by barrier membrane **30**. Compartment **28** may include an activator, such as an acid, while compartment **32** includes a chlorite or chlorate reactant. The GG subsystems are in turn enclosed within barrier sachet **26**, the RHC subsystem being provided by hygrostatic material contained within sachet **26** external to the GG subsystems. Sachet **26** is in turn contained within an outer shipping envelope 24 of substantially impermeable material, such as a foil packet. In use, envelope **24** is removed, to expose sachet **26** to ambient moisture, and thereby activate chlorine dioxide gas generation within each GG subsystem **28**, **30**, **32**, with the external RHC subsystem within sachet **26** modulating the water vapor partial pressure within the sachet **26**, to regulate the rate of chlorine dioxide gas generation.

[0024] A variety of activators and reactants may be used in alternative embodiments, for example in the form of dry materials contained in the GG subsystem. Dry particles may for example be sized so as to provide a desired degree of reactivity, with smaller particles generally corresponding to more rapid reaction conditions. In select embodiments, the reactant is a solid metal chlorite and the activator is a solid acid, each being capable of dissolution or entrainment in aqueous medium so as to combine in a reaction effective to form chlorine dioxide. This reaction of a chlorite with an acid to form chlorine dioxide may for example be represented as follows (Deshwal & Lee, 2005):

$$4ClO_2^- + 2H^+ \rightarrow 2ClO_2 + ClO_3^- + Cl^- + H_2O.$$

For a reaction of sodium chlorite with citric acid ($C_6H_8O_7$) this equation may be represented as:

$$4NaClO_2 + 2C_6H_8O_7 \rightarrow 2ClO_2 + NaClO_3 + NaCl + H_2O + 2NaC_6H_7O_7.$$

[0025] Where the metal chlorite comprises predominantly a selected metal chlorite, or chlorate, such as sodium chlorite, additional components may also be present, such as compositions of approximately 80% by weight sodium chlorite and

20% by weight of sodium chloride, sodium chlorate and other components. Alternative chlorites include calcium chlorite, barium chlorite, magnesium chlorite, potassium chlorite, alkali metal chlorites, alkaline earth metal chlorites, and mixtures thereof.

[0026] An activator for oxidation of a chlorite reactant may be provided by a dry solid hydrophilic acid or oxidant, such as one or more of: citric acid, phosphoric acid, acetic acid, adipic acid, boric acid, formic acid, glutaric acid, hydrochloric acid, lactic acid, maleic acid, mandelic acid, malic acid, sulfuric acid, sodium persulfate, sodium bisulphate, phosphoric anhydride, sulfuric anhydride, maleic anhydride, calcium chloride, magnesium chloride, magnesium nitrate, lithium chloride, magnesium sulfate, aluminum sulfate, sodium acid sulfate, sodium dihydrogen phosphate, potassium acid sulfate, potassium dihydrogen phosphate and/or tartaric acid.

[0027] In alternative embodiments, the GG subsystem need not include a membrane or barrier separating the activator and the reactant, and instead one or both of these components may be provided in medium such as a polymer matrix or on a solid particulate surface, so as to remove the necessity for a physical barrier separating the reactants. The device of **Figure 2**, may for example lack membrane barrier **30**. The chlorine dioxide generating reaction may for example take place in a polymer matrix in the presence of moisture (Saade et al., 2017 and 2018), for example in a poly (ether-block-amide) hydrophilic polymer (Sadeghi et al., 2020). Alternative solid GG reaction media may for example include: zeolite, kaolin, mica, bentonite, sepiolite, diatomaceous earth synthetic silica, and the like. US Patent No. 6,294,108 for example describes a metakaolin powder adapted for this purpose, to provide an acid activator for a reaction with solid sodium chlorite that is intermixed with the metakaolin powder.

[0028] Vapor and fluid flows in chlorine dioxide generating devices may be regulated by a variety of barrier or membrane materials. In select embodiments, the barrier membrane in the GG subsystem is composed of an absorbent material that is capable of separating dry reactants while absorbing and transporting aqueous entrained reactants, to facilitate the chlorine dioxide generating reaction. This barrier membrane accordingly serves the purpose of transferring water, in vapor and/or liquid form, from one compartment of the GG subsystem to the other. This membrane may accordingly have a relatively high absorbency for aqueous materials, while maintaining structural integrity for physical separation of solids in the presence of a highly acidic and oxidative environment. Materials meeting these requirements may for example be comprised of natural or synthetic fibres or polymers, such as: cellulosic materials, rayon, ethyl cellulose, cellulose acetate, polyvinyl chloride, polyvinyl fluoride, polytetrafluoroethylene, polyvinylidene chloride, polyacrylics, polyvinyl acetate, polyethylvinyl acetate, non-soluble and soluble polyvinyl alcohol, polyolefins such as polyethylene and polypropylene, polyamides such as nylon, polyesters, polyurethanes and polystyrenes. These membrane materials may be woven or non-woven.

[0029] Barriers and membranes may also be provided that are water resistant, water vapor permeable and chlorine dioxide gas permeable, which provide physically and chemically robust barriers to separate or contain solid materials. Materials for such barriers or membranes will generally be relatively hydrophobic, in contrast to the relatively hydrophilic barriers or membranes with the GG subsystem. These water-resistant materials may be natural or synthetic, woven or non-woven, coated or non-coated, single or multi-layered, and may for example comprise: polyacrylics, polyamides, polyesters, polyethylene, polyethylvinyl acetate, polyolefins, polypropylene, polystyrenes, polytetrafluoroethylene, polyurethanes, polyvinyl acetate, polyvinyl alcohol, polyvinyl chloride, polyvinyl fluoride and/or polyvinylidene chloride. Micro porous non-woven polyethylene, polypropylene or expanded polytetrafluoroethylene polymer sheet materials may provide such water-resistant membranes or barriers, such as Tyvek® or Gore-Tex® brand materials.

[0030] The present devices may be contained, or packaged for shipment and storage, in containers made of materials which are resistant to the passage of liquid water and water vapor, as for example illustrated by the circumferential cylindrical walls of **Figure 1** and envelope **24** in **Figure 2**. Examples of such materials include metal, glass, foil pouches, and barrier layer polymer laminates.

[0031] Housings for sustained chlorine dioxide gas generation systems may be adapted to be variably permeable, and thereby constructed so as to permit manual or automated adjustment of gas, including moisture, inflow and egress from the system. A housing may for example include movable or slidable interdigitating components with variably permeable sections of the housing being exposed, or not exposed, and thereby being made available for gas transport, depending on the positioning of the movable or slidable components. Mechanical housings may also be provided with locking or tamper proofing mechanisms, to inhibit access to interior reactants.

[0032] The compartments of the GG subsystem may include various materials in addition to the activator and the chlorite reactant. For example, deliquescent materials may be provided to facilitate the collection of liquid water for purposes of mediating the chlorine dioxide generating reaction. These deliquescent materials may for example include one or more deliquescent salts, such as: aluminum chloride, ammonium chloride, ammonium sulphate, anhydrous sodium sulfate, barium chloride, calcium chloride, calcium nitrate, calcium sulphate, lithium chloride, magnesium acetate, magnesium chloride, magnesium nitrate, potassium bromide, potassium carbonate, potassium chloride, potassium sulphate, sodium carbonate, sodium chloride, sodium nitrite and/or sodium phosphate.

[0033] Any deliquescent materials in the GG subsystem may be selected to work in combination with the hygrostatic materials in the RHC subsystem of the chlorine dioxide generator. Both materials may advantageously be selected so as to achieve by combined action a desired relative internal humidity, or water vapor partial pressure, within the device, applying principles as for example described in WO2009097093A1.

[0034] The RHC subsystem provides a mechanism for controlling the relative humidity inside the device, to support a desired level of chlorine dioxide generation. The hygroscopic material in the RHC may be selected so as to provide a desired two-way humectant capacity, for example being capable of collecting from an ambient atmosphere, by adsorbing or absorbing, 0.1, 1, 5, 10, 20, 30, 40, 50 or more grams of liquid, and in addition being capable of releasing to the interior of the device, by evaporation or otherwise, at least 0.001, 0.01, 0.1, 0.2, 0.3, 0.4 or 0.5 grams of water vapor per hour, or more depending on the size or the unit, or at least 0.5, 0.75, 1, 5 or 10 grams of water vapor per 24 hour period, for example for an extended time such as 1-30 days, or 1-6 months, or more.

[0035] Hygroscopic materials may for example include a salt or hydrophilic compound capable of forming a saturated aqueous solution of a solute that inherently creates a desired relative humidity in an adjoining air space connected to the RHC. Various salts may be used to prepare the salt solution. For example, the solute may be a single salt such as sodium chloride, calcium chloride, sodium nitrite, potassium nitrite, ammonium nitrate, ammonium carbonate or a mixture of salts. The hygrostatic material may also include, or be made up of, non-ionic compounds such as sugars (e.g.sucrose, fructose, glucose, galactose), sugar alcohols (e.g. sorbitol, xylitol, and mannitol), polybasic acids (e.g. citric, maleic, malic, and succinic), and salts of polybasic acids (e.g. sodium citrate, sodium malate, and sodium tartrate). In some embodiments, a saturated solution of sodium chloride, with excess solid crystals of sodium chloride, may for example provide a relative humidity inside the device of about 74%. Alternative saturated salt formulations provide alternative humidity levels, such as potassium sulfate at 97%, potassium nitrate at 92%, cesium iodide at 91%, and barium chloride at 90%, potassium chloride at 84%, sucrose at 84%, ammonium sulfate at 81 %, potassium bromide at 81%, sodium nitrate at 74%, strontium chloride at 71%, potassium iodide at 69%, sodium nitrite at 66%, sodium bromide at 58%; sodium dichromate at 55%; magnesium nitrate at 53%, potassium carbonate at 44%, sodium iodide at 38%, magnesium chloride at 33%, calcium chloride at 29%, lithium iodide at 18%, lithium chloride at 11%, potassium hydroxide at 9%, zinc bromide at 8% and lithium bromide at 6%. A wide variety of salts or combinations of salts can accordingly be used to mediate a wide range of relative humidity levels within the device.

[0036] The hygroscopic material may further include a gel forming material such as analginate or xanthan. The hygroscopic material may for example be provided as a viscous fluid, contained in a barrier or membrane material, such as polymeric pouch. Examples of prospective membrane or barrier materials for this purpose include films of polyethylene or polystyrene, polymeric films laminated to a support, such as a paper or polyester support, nylon films, styrene-butadiene copolymers. Relative humidity levels may for example be controlled by providing a desiccant and a humectant as components of RHC subsystem, with the desired humidity being a function of the mass distribution of water there between, as for example described in WO2009097093A1.

[0037] The RHC may optionally include a liquid water supply external to the system and in fluid communication with the RHC subsystem, adapted so as to maintain the relative humidity in the container higher than the average external humidity by providing a source of water for humidity generation by the RHC.

[0038] Barriers or membranes for use with the RHC may be selected based on a desired water vapor transmission rate (WVTR), for example transmitting about 0.001, 0.01, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more grams of water per 100 square inches in 24 hours. Films that may meet such requirements include films of polyvinylchloride, microfiberous polyethylene, microporous polyethylene, high density polyethylene, oriented polystyrene, cellophane, polycarbonate, and the like that have WVTR of 3 grams or more. Alternatives may include polyesters, polyamides, polyurethane, ethylcellulose, cellulose acetate, polybutylene, polyethylene terphatlate, polyvinylchoride, nylon, polyvinylfluoride, ethylenevinylacetate K-Resins and polyvinylalcohol films.

[0039] In select embodiments, devices may be provided with a scent indicator, for example in the form of a plant extract, such as terpenes and essential oils. This scent may be provided in an amount, such as a trace amount, that is susceptible to degradation by chlorine dioxide gas for the duration of the chlorine dioxide generation process, but detectable when that degradation is no longer effective, so as to provide a detectable indicator that chlorine dioxide gas is no longer being generated in a desired amount. In alternative embodiments, scent control systems, as for example described in US20190369576A1, may be integrated with chlorine dioxide generating systems.

[0040] Ambient and internal levels of humidity play a role in the chlorine dioxide generating processes described herein. Accordingly, in some embodiments, a humidity indicator, such as a humidity indicating card, may be affixed to or packaged with devices disclosed herein, such as humidity indicating cards disclosed in U.S. Pat. No. 9,618,456 or WO2013005974A3.

[0041] As used herein, the term "substantially impermeable" refers a threshold of permeability that approaches, but does not necessarily achieve complete or 100% impermeability. A material is considered to be substantially impermeable if the degree to which it is permeable is insignificant with respect to the desired application for which the material is being used. Depending upon the use of the material, 99.9%, 99%, 98%, etc. may qualify as being "substantially impermeable." A skilled artisan is able to determine whether a material is "substantially impermeable" for a given use.

[0042] In another aspect, distributed chlorine dioxide gas systems are provided, configured for the controlled distribution of chlorine dioxide gas in a defined space. The systems may include a variety of chlorine dioxide gas generation (GG) subsystems, such as the GG subsystems disclosed herein, comprising an activator, and a chlorite or chlorate reactant. A metered or controlled aqueous reaction medium release mechanism may be provided, to regulate ClO_2 gas generation. A reaction rate control (RRC) subsystem may also be provided, including one or more chlorine dioxide gas sensors, such as photo-ionization (PID) or electrochemical (see US20190033246) ClO_2 sensors, distributed in the defined space, including sensors that are portable and/or wearable. These sensors may be configured to communicate, for example wirelessly, chlorine dioxide gas concentration information to the GG subsystem. A control system may be provided that is configured for modulating the metered release of the aqueous GG reaction medium from the metered aqueous reaction medium release mechanism. The metered release of this medium may be controlled in response the chlorine dioxide gas concentration information provided by the RRC subsystem. In this way, the control system modulates desired concentrations of chlorine dioxide gas in the space. Distributed systems may for example be configured to modulate the generation of ClO_2 based on the relative pressure of the defined space served by the system, for example to selectively generate ClO_2 when the defined space is under negative pressure (as for example described in WO2010045619 and US20050019210).

[0043] Distributed chlorine dioxide gas generating systems may also be provided with humidity control systems in the defined space, with humidity sensors distributed in the defined space. The sensors communicate, for example wirelessly, humidity information to the control system, and the control system may in tern modulate the metered release of the aqueous GG reaction medium based on the humidity information.

[0044] Chlorine dioxide and/or humidity and/or temperature sensing systems that are components of a distributed chlorine dioxide gas generating system may for example be attached (for example removably attached) to an object (such as personal protective equipment, or a wall) within the space serviced by the system. The sensing systems may be capable of measuring, recording, and transmitting the values representative of the local environment, for example chlorine dioxide concentrations, humidity and temperature. Sensing systems may be single use, multiple use, disposable, and/or re-usable. Embodiments accordingly provide sensing systems for measuring, storing, and transmitting the values of environmental variables associated with the local environment of a defined space serviced by the distributed chlorine dioxide generating system, for example chlorine dioxide concentrations, humidity and temperature. Sensing systems may include a microprocessor (or computing device) with a memory, means of transmitting information wirelessly, an antenna, a power supply, and a sensor configured to measure at least one environmental parameter, such as chlorine dioxide concentrations, humidity and temperature. In this context, means of transmitting information wirelessly may for example include one or more of a Wi-Fi chip; a wireless radio, a near field communication chip, a radio frequency identification chip; or a cellular chip. Data reflecting the local conditions with the defined space may for example be transmitted to one or more of a Wi-Fi router, a smart phone, a gateway device, sensor control unit or cellular receiver.

[0045] Distributed chlorine dioxide gas generating systems may be configured to maintain a concentration of chlorine dioxide gas in the space that is at or below a ClO_2 gas maximum threshold and/or a minimum threshold. The ClO_2 gas maximum threshold may for example be 0.1 or 0.2 or 0.3 or 0.4 or 0.5 or 0.6 or 0.7 or 0.8 or 0.9

or 1.0 ppm. Chlorine dioxide gas abatement systems, such as absorbers or dissipaters, may be distributed in the defined space, and may be configured to be actuatable by the control system, or manually, to reduce the level of chlorine dioxide gas in the space, for example when the concentration of the chlorine dioxide gas is at or above the ClO_2 gas maximum threshold. The ClO_2 gas minimum threshold may for example be equal to or less than 0.009, 0.01 or 0.02 or 0.03 or 0.04 or 0.05 or 0.06 or 0.07 or 0.08 or 0.09 ppm

[0046] Chlorine dioxide gas absorbers may for example include adsorbents, such as activated carbon or analogous adsorption units, as for example described in WO2017035023A1 (see also Wood et al., 2010, J Air Waste Manag Assoc. Aug;60(8):898-906). Chlorine dioxide gas dissipaters may for example include UV light generating systems, which operate on the principle that ClO_2 is labile to UV illumination. A UV-based ClO_2 gas dissipater may for example comprise a UV light source emitting a ClO_2-decomposing wavelength of light, and may have a fan for moving a ClO_2-containing gas past the light source, to thereby reduce the concentration of ClO_2 in a volume of gas that passes through the dissipater. UV light is also an effective antiseptic, and UV-based ClO_2 gas dissipaters may accordingly be configured to also optionally provide for UV sterilization of the defined spaces in which ClO_2 gas generating systems are deployed. UV units of this kind may for example comprise an openable window into a UV-illuminated space, so that when the window is opened UV light is emitted into the surrounding space to provide a sterilizing light treatment to the space, and when the window is closed the UV-illuminated space serves as a confined space within which a moving gas, for example being moved by a fan, may be treated to reduce the concentration of chlorine dioxide therein.

[0047] A clock mechanism may be provided in distributed chlorine dioxide gas generating systems, so that the control system can temporally modulate the concentration of chlorine dioxide gas in the space, for example mediating higher ClO_2 concentrations when the space is not occupied (and motion sensors may be provided to provide the control system with an indication of occupancy of the defined space).

[0048] Manual controls may be provided for adjusting the desired concentration of chlorine dioxide gas in the space, and a locking mechanism may be included to restrict access to the system, particularly the manual controls. Controls may for example be provided in the defined space. For example, in an inhabited space defined by walls, controls may be provided in the walls of the space, so that occupants of the space can modulate the operation of the control system that modulates the concentration of chlorine dioxide in the space. In a locked defined space, the control systems may similarly be provided with locks that inhibit access to the control system, and the locks on the control system may for example be actuated by a common or distinct key from the key that actuates the locks on the defined space.

[0049] A wide variety of ClO_2 gas generating technologies may be incorporated into distributed chlorine dioxide gas generating systems. These technologies may be selected in part based on the scale of the installation, for example for areas the size of a residential space, vehicle, office building, greenhouse, hotel, casino, prison, hospital, nursing or retirement home, passenger ship or other marine vessels. The GG subsystems may for example include fixed or portable ClO_2 generators, and may be incorporated into air handling or HVAC systems.

[0050] Distributed ClO_2 generating systems may for example include electrolytic ClO_2 gas generators, as for example disclosed in WO2018203158A1, WO2018043711A1, US9776163, US20160186340A1 and US20170253980A1.

[0051] Chlorine dioxide gas generating masks and personnel coverings are also provided, including masks and coverings that include a desiccant that inhibits transmission of anthropogenic or exhaled moisture into a ClO_2 generating subsystem. In some embodiments, an anthropogenic humidity control (AHC) subsystem, comprising a desiccant, may for example inhibit transmission of excess moisture while permitting transmission of a desired amount of anthropogenic moisture to facility the ClO_2 generating reaction. Facemasks may for example be provided that filter inhaled and exhaled air, for example so as to reduce transmission of pathogens using including one or more discrete nanofiber layers, with or without indicators, such as a chromogenic ClO_2 indicator, included in the mask (see for example US20160015098A1, US20050133034A1, US20060094320A1, US20070023046A1, US20080160856A1, US20080264258A1, US20080264259A1, US20090205666A1, US20110259813A1 and US20110271955A1). The ClO_2 generating and humidity controlling subsystems or modules may be integral to the personnel covering, or may be replaceable (see for example replaceable mask assemblies described in US20200114178A1).

[0052] Wearable chlorine dioxide generating systems are provided that are configured to emit ClO_2 gas for inhalation by the wearer. Systems of this kind may include a ClO_2 gas transmission conduit, in fluid communication with a GG subsystem, in which the ClO_2 gas transmission conduit includes an outlet positionable in proximity to a wearer's face. This may for example take the form of a ClO_2 conduit adapted to hang from a wearer's neck, with a gas outlet positioned in proximity to a wearer's face. In select embodiments, relatively small chlorine dioxide generating systems may be provided, for example being pocket sized, that connect to a ClO_2 delivery tube, which in turn connects to a head-mounting apparatus to position the ClO_2 outlet in proximity to the wearer's face. Units of this kind may for example also be wired for a microphone, to enable a dual function and in effect provide for a self-sterilizing personal microphone apparatus. Units of this kind may for example be programmed to respond to a command to increase, or decrease, the ClO_2 gas generation level. Alternatively, these units may be provided with proximity detectors, so that ClO_2 gas generation levels are modulated when people approach the wearer. In this way, personal GG subsystems may be actuated to increase ClO_2 generation when someone approaches the wearer. Similar actuation systems may also be provided on masks or other PPE, for example for health care workers, to provide variable amounts of ClO_2 gas on demand or in response to detected situational information.

[0053] Copper may be included in chlorine dioxide abatement systems, including as a component of personnel coverings such as masks. Chlorine dioxide is a strong oxidizing agent, capable of oxidizing metallic copper and being degraded in the process (see Vertova et al., 2019, Int J of Env Res and Pub Health 16, 4582; Zhang, et al., 2008, Water Res., 42, 129–136; and, Liu, et al., 2013, Environ. Sci. Technol., 47, 8365–8372). The oxidation of copper by chlorine dioxide may form copper oxides and/or chlorides, in some embodiments this reaction may accordingly result in a color change that indicates that the copper has reacted, thereby indicating that the copper is no longer available to abate chlorine dioxide (for example providing an indication that a disposable personnel covering that includes a copper-containing ClO_2 abatement system should be discarded). In alternative embodiments, a copper mesh, and/or activated charcoal, may be incorporated into masks to be worn in environments in which relatively high concentrations of ClO_2 are deployed, the copper and/or charcoal serving to ameliorate the exposure of personnel to these high levels of ClO2 and thereby facilitate the use of these higher levels of ClO2 to effect an antiseptic or odor abatement function.

[0054] A wide variety of configurations are provided for alternative chlorine dioxide generating systems, of various sizes. Containers or housing are for example provided, similarly constructed to the embodiment illustrated in **Figure 2**, that include a two chambered packet **28, 30, 32** with water permeable membranes between chambers **28** and **32**, and on the outside of chambers **28, 32**, to allow water into acid chamber **28**, through membrane **30**, then through chlorite and buffer chamber **32** and out through an exterior packet membrane, then through holes in container housing **24**, into the treated room space, with housing **24** for example taking the form of an enclosed clamshell of plastic having exhaust holes into the room. Alternative embodiments may include a three chamber packet with water permeable membranes between and on outside, or sealed on outside of water-providing RHC chamber **26**, to allow water into acid chamber **28**, through membrane **30**, through chlorite and buffer chamber **32** and out through exterior packet membrane, through holes in container housing **24**, into the treated room space, with the enclosed housing **24** forming a clamshell of plastic having exhaust holes to the room. Two or three chamber packet arrangements of this kind may for example be provided in housings that are provided with elevating feet and holes on the bottom of the housing, so as to facilitate air flow there through. Housings may alternatively have one or more elevated, perforated platforms inside the housing, for example with holes on lower edges to allow air flow through the housing from the bottom. Alternatively, housings may be sealed except for holes on top that allow gas to escape to the treated space.

[0055] Containers may be provided with two one chamber packets with water permeable membranes on both sides but separated by an internal, adjustable barrier with holes. Containers of this kind may have feet and holes on the bottom to allow air flow through the container from the bottom. Such containers may optionally have elevated, perforated platforms inside the container with holes on lower edges to allow air through from bottom, which allows water into acid chamber, through membrane, exiting through an internal, adjustable barrier with holes, through chlorite and buffer chamber and out through membrane into the container space in the enclosed clamshell of plastic and through the container exhaust holes to the treated room space.

[0056] Containers may be provided with the two one chamber packets, with water permeable membranes on both sides but separated by a fixed barrier with holes. Containers of this kind may have feet and holes disposed on a bottom surface thereof, for example with a variable adjustment plate or mechanism, to allow air flow there through from the bottom. Optionally one or more elevated, perforated platform may be provided inside the container with holes on lower edges, with a variable adjustment plate or mechanism, to allow moist air flow through from the bottom, which then allows water into acid chamber, through membrane, exiting through internal, fixed barrier with holes, through chlorite and buffer chamber and out through a membrane into the container space in the enclosed clamshell of plastic, and through the container exhaust holes to the treated room space.

[0057] Containers may be provided with the two one chamber packets and one single chamber packet with water permeable membranes on both sides but separated by two internal, adjustable barriers with holes. Containers of this kind may have feet and perforations disposed on a bottom surface thereof, so as to allow air flow through the container from the bottom. Elevated, perforated platforms may be provided inside the container, with holes on lower edges thereof to allow air flow there through from the bottom, which allows water into moisture providing packet, through internal adjustable barrier, into the acid chamber, through membrane, exiting through internal, adjustable barrier with holes, through chlorite and buffer chamber and out through membrane into the container space in the enclosed clamshell of plastic, and finally through the container adjustable exhaust holes to the treated room space.

[0058] Containers may be provided that include two one chamber packets and one single chamber packet with water permeable membranes on both sides but separated by two internal, barriers with holes. Containers of this kind may be sealed on the bottom, and may contain the moisture generating RHC packet. This arrangement allows water from moisture providing RHC packet, through internal adjustable barrier, into acid chamber, through membrane, exiting through internal, fixed or adjustable barrier with holes, through chlorite and buffer chamber and out through membrane into the container space in the enclosed clamshell of plastic, and then through the container-adjustable exhaust holes to the treated room space.

[0059] Alternative embodiments may involve stimulating air movement by addition of electronic or mechanical fans, for example powered by standard current, induction, solar or battery. For adjustable barriers, each may be adapted to provide differently sized hole arrays, so as to provide air and moist air movement control by simple adjustment of the position of the barrier. These barriers may for example be comprised of one or two adjustable plates. Adjustments may for example be made to calibration lines that will delineate the moisture flow and or gas release inside or from the unit. Adjustments may for example be manually made or motivated by electronic controls, including computer programs.

[0060] ClO_2 generators may be produced in a very wide range of sizes, for example to be placed into air handling systems or in alternative parts of an occupied space. Containers are optionally provided with compartments that seal, comprising for example 1, 2, 3, 4 or 5 sealable compartments. Containers may also optionally be provided with manual, mechanical or electrically controlled adjustable barriers, to modulate moisture or gas movement between chambers and the contents thereof. The contents of the chambers and/or compartments may for example be provided in replaceable packets or other interchangeable formats, such as cartridges that lock in place inside a chamber. Containers can be provided in a very wide range of sizes. Electronic controls may for example be enabled to communicate electronically, for example by Bluetooth, Wi-Fi, or radio frequency panel. Controls may optionally have proximity sensor or motion sensor, for example to actuate GG systems when someone approaches, so that a larger metered dose is generated for a period of time to disinfect an area that is, or has been, detectably occupied. Conversely, GG systems may be reduced in activity when spaces are not, or have not been, occupied.

[0061] Small units can be placed in various parts of buildings so that more trafficked areas get slightly higher dosing. Units can be placed in building entrances where existing walk through metal detection is done. The area inside the walk-through zone can be higher levels of gas as well.

[0062] In select embodiments, in addition to or instead of RHC subsystems, ClO_2 generation systems may be made to have an alternative, precisely controlled, water source, such a water allocation subsystem in fluid communication with a water container or water line. In such embodiments, relatively small units may be provided that only require acid and chlorite packet replacement.

EXAMPLES

Example 1: Murine coronavirus

[0063] Mouse hepatitis virus (MHV) is a strain of murine coronavirus, an enveloped, positive-sense, single-stranded pathogenic RNA virus in the genus *Betacoronavirus*, subgenus *Embecovirus*. In this Example, 100 µl aliquots of MHV in phosphate buffered saline (PBS) were exposed to gaseous chlorine dioxide in a sealed container, with gentle stirring of the liquid below the ClO_2 atmosphere. Aqueous MHV virus was treated in this way for 0, 1, 2, 5, 10 and 15 min, at ~0.05 ppm ClO_2 in air. The reduction in MHV viability was assessed in a viral plaque formation assay. The results indicated that with ~0.05 ppm ClO_2, 89% of the MHV virus was inactivated after 1 minute, as summarized in Table 1 below.

Table 1: Treatment of MHV with ClO_2 ~0.05 ppm

Treatment time (min)	0	1	2	5	10	15
Percent reduction in MHV viability	0%	89%	92%	97%	98%	99.6%

Example 2: SARS-CoV-2

[0064] In this Example, aqueous suspensions of the human coronavirus pathogen SARS-CoV-2 were treated with gaseous ClO_2 in air, in the same manner as the treatment of MHV in Example 1. In particular, 100 µl aliquots of SARS-CoV-2 in PBS were exposed to gaseous chlorine dioxide in a sealed container, with gentle stirring of the liquid below the ClO_2 atmosphere. Aqueous SARS-CoV-2 virus was treated in this way for 0, 1, 2, 5, 10 and 15 min, at ˜0.05 ppm ClO_2 in air. The reduction in SARS-CoV-2 viability was assessed in a viral plaque formation assay. The results indicated that with ˜0.05 ppm ClO_2, >90% of the SARS-CoV-2 virus was inactivated after 10 minutes, as summarized in Table 2 below.

Table 1: Treatment of SARS-CoV-2 with ClO_2 ~0.05 ppm

Treatment time (min)	0	1	2	5	10	15
Percent reduction in SARS-CoV-2 viability	0%	72%	68%	87%	96%	94%

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[0086] Citation of references herein is not an admission that such references are prior art to the present invention. Any priority document(s) and all publications, including but not limited to patents and patent applications, cited in this specification, and all documents cited in such documents and publications, are hereby incorporated herein by reference as if each individual publication were specifically and individually indicated to be incorporated by reference herein and as though fully set forth herein.

[0087] Although various embodiments of the invention are disclosed herein, many adaptations and modifications may be made within the scope of the invention in accordance with the common general knowledge of those skilled in this art. Such modifications include the substitution of known equivalents for any aspect of the invention in order to achieve the same result in substantially the same way. Terms such as “exemplary” or “exemplified” are used herein to mean “serving as an example, instance, or illustration.” Any implementation described herein as “exemplary” or “exemplified” is accordingly not to be construed as necessarily preferred or advantageous over other implementations, all such implementations being independent embodiments. Unless otherwise stated, numeric ranges are inclusive of the numbers defining the range, and numbers are necessarily approximations to the given decimal. The word "comprising" is used herein as an open-ended term, substantially equivalent to the phrase "including, but not limited to", and the word "comprises" has a corresponding meaning. As used herein, the singular forms "a", "an" and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a thing" includes more than one such thing. The invention includes all embodiments and variations substantially as hereinbefore described and with reference to the examples and drawings. In some embodiments, the invention excludes steps that involve medical or surgical treatment.

CLAIMS

1. A sustained chlorine dioxide gas generating system, comprising:

a chlorine dioxide gas generation (GG) subsystem, comprising an activator and a chlorite or chlorate reactant in a GG container that is water vapor permeable and chlorine dioxide gas permeable;

a relative humidity control (RHC) subsystem, comprising a hygrostatic material that absorbs water vapor above an upper water vapor partial pressure and releases water vapor below a lower water vapor partial pressure, in an RHC container that is water vapor permeable and chlorine dioxide gas permeable; and,

a housing that is water vapor permeable and chlorine dioxide gas permeable, the housing containing therein the GG subsystem and the RHC subsystem, wherein the housing permits the ingress of water vapor at an ambient humidity, the RHC subsystem modulates the water vapor partial pressure within the housing, and the housing permits the egress of a chlorine dioxide gas evolved from the GG subsystem by a ClO_2 reaction between the activator and the reactant, where the ClO_2 reaction is modulated by the water vapor partial pressure within the housing.

2. The system of claim 1, wherein the activator comprises an acid or oxidative activator.

3. The system of claim 2, wherein the activator comprises: citric acid, phosphoric acid, acetic acid, adipic acid, boric acid, formic acid, glutaric acid, hydrochloric acid, lactic acid, maleic acid, mandelic acid, malic acid, sulfuric acid, sodium persulfate, sodium bisulphate, phosphoric anhydride, sulfuric anhydride, maleic anhydride, calcium chloride, magnesium chloride, magnesium nitrate, lithium chloride, magnesium sulfate, aluminum sulfate,

sodium acid sulfate, sodium dihydrogen phosphate, potassium acid sulfate, potassium dihydrogen phosphate, tartaric acid or a mixture thereof.

4. The system of any one of claims 1 to 3, wherein the chlorite reactant comprises a solid metal chlorite.

5. The system of claim 4, wherein the solid metal chlorite comprises: sodium chlorite, calcium chlorite, barium chlorite, magnesium chlorite, potassium chlorite, an alkali metal chlorite, an alkaline earth metal chlorite, or a mixture thereof.

6. The system of any one of claims 1 to 5, wherein the hygrostatic material comprises: sodium chloride, calcium chloride, sodium nitrite, potassium nitrite, ammonium nitrate, ammonium carbonate or a mixture thereof.

7. The system of any one of claims 1 to 6, wherein the hygrostatic material comprises: sucrose, fructose, glucose, galactose, sorbitol, xylitol, mannitol, citric acid, maleic acid, malic acid, succinic acid, sodium citrate, sodium malate, sodium tartrate or a mixture thereof.

8. The system of any one of claims 1 to 7, wherein the hygroscopic material comprises a gel forming material.

9. The system of any one of claims 1 to 8, wherein the GG subsystem further comprises a deliquescent material.

10. The system of claim 9, wherein the deliquescent material comprises: aluminum chloride, ammonium chloride, ammonium sulphate, anhydrous sodium sulfate, barium chloride, calcium chloride, calcium nitrate, calcium sulphate, lithium chloride, magnesium acetate, magnesium chloride, magnesium nitrate, potassium bromide, potassium carbonate, potassium

chloride, potassium sulphate, sodium carbonate, sodium chloride, sodium nitrite, sodium phosphate or a mixture thereof.

11. The system of any one of claims 1 to 10, wherein the GG container is water resistant.

12. The system of any one of claims 1 to 11, wherein the RHC container is water resistant.

13. The system of any one of claims 1 to 12, wherein the housing is water resistant.

14. A method of providing chlorine dioxide to a space, comprising operating the system of any one of claims 1 to 13 in the space.

15. The method of claim 14, further comprising operating a humidifier in the space to increase the ambient humidity.

16. A distributed chlorine dioxide gas generating system in a defined space, comprising:

a chlorine dioxide gas generation (GG) subsystem, comprising an activator, a chlorite or chlorate reactant, and a metered aqueous reaction medium release mechanism;

a reaction rate control (RRC) subsystem, comprising one or more chlorine dioxide gas sensors distributed in the defined space, communicating chlorine dioxide gas concentration information to the GG subsystem; and,

a control system modulating the metered release of an aqueous GG reaction medium from the metered aqueous reaction medium release mechanism in response the chlorine dioxide gas concentration information provided by the RRC subsystem, wherein the control system thereby modulates desired concentrations of chlorine dioxide gas in the space.

17. The distributed chlorine dioxide gas generating system of claim 16, further comprising a humidity control system in the defined space, the humidity control system comprising humidity sensors distributed in the defined space, communicating humidity information to the control system modulating the metered release of the aqueous GG reaction medium, wherein the control system modulates the metered release of the aqueous GG reaction medium based on the humidity information.

18. The distributed chlorine dioxide gas generating system of claim 16 or 17, wherein the control system is configured to maintain a concentration of chlorine dioxide gas in the space that is at or below a ClO_2 gas maximum threshold.

19. The distributed chlorine dioxide gas generating system of claim 18, wherein the ClO_2 gas maximum threshold is 0.1 or 0.2 or 0.3 or 0.4 or 0.5 or 0.6 or 0.7 or 0.8 or 0.9 or 1.0 ppm.

20. The distributed chlorine dioxide gas generating system of claim 18 or 19, further comprising one or more actuatable chlorine dioxide gas absorbers distributed in the defined space, the absorbers being actuatable by the control system to reduce the level of chlorine dioxide gas in the space when the concentration of the chlorine dioxide gas is at or above the ClO_2 gas maximum threshold.

21. The distributed chlorine dioxide gas generating system of any one of claims 16 to 20, wherein the control system is configured to maintain a concentration of chlorine dioxide gas in the space that is at or above a ClO_2 gas minimum threshold.

22. The distributed chlorine dioxide gas generating system of claim 21, wherein the ClO_2 gas minimum threshold is equal to or less than 0.009, 0.01 or 0.02 or 0.03 or 0.04 or 0.05 or 0.06 or 0.07 or 0.08 or 0.09 ppm.

23. The distributed chlorine dioxide gas generating system of any one of claims 16 to 22, wherein one or more of the chlorine dioxide gas sensors are portable and/or wearable.

24. The distributed chlorine dioxide gas generating system of any one of claims 16 to 22, wherein the control system comprises a clock, and the control system temporally modulates the concentration of chlorine dioxide gas in the space.

25. The distributed chlorine dioxide gas generating system of any one of claims 16 to 22, wherein the control system comprises manual controls for adjusting the desired concentration of chlorine dioxide gas in the space.

26. The distributed chlorine dioxide gas generating system of any one of claims 16 to 25, further comprising a locking mechanism to restrict access to the system.

27. A sustained chlorine-dioxide-gas-generating personnel covering system, comprising:

a chlorine dioxide gas generation (GG) subsystem, comprising an activator and a chlorite or chlorate reactant in a GG container that is water vapor permeable and chlorine dioxide gas permeable;

an anthropogenic humidity control (AHC) subsystem, comprising a desiccant that absorbs water vapor, in an AHC unit that is water vapor permeable and chlorine dioxide gas permeable, the AHC unit enveloping the GG subsystem; and, a personnel covering supporting the GG subsystem enveloped by the AHC unit, the personnel covering being configured to cover a body portion of a wearer while permitting air comprising anthropogenic humidity generated by the wearer to contact the AHC subsystem, the AHC subsystem being configured to modulate water vapor partial pressure within the GG subsystem, the AHC unit being configured to permit the egress of a chlorine dioxide gas evolved from the GG subsystem by a ClO_2 reaction between the activator and the reactant, where the ClO_2 reaction is modulated by the water vapor partial pressure within the GG subsystem.

28. The personnel covering system of claim 27, wherein the covering comprises a facemask configured to substantially cover the wearer's mouth and/or nose and to filter air inhaled and/or exhaled by the wearer while permitting exhaled air comprising exhaled humidity to contact the AHC subsystem.

29. The personnel covering system of claim 27 or 28, wherein the personnel covering removably supports the GG subsystem enveloped by the AHC unit, the GG subsystem and/or AHC subsystem being removable from the personnel covering.

30. The personnel covering system of any one of claims 27 to 29, wherein the GG subsystem is releasably enveloped by the AHC unit, the GG subsystem being removable from the AHC unit.

31. The personnel covering system of any one of claims 27 to 30, further comprising a chlorine dioxide abatement system configured to dissipate chlorine dioxide.

32. The personnel covering system of claim 31, wherein the chlorine dioxide abatement system comprises metallic copper.

33. Use of the system of any one of claims 1 to 13 or 16 to 32, for odor control.

34. Use of the system of any one of claims 1 to 13 or 16 to 32, to inhibit growth or distribution of a microbial pathogen.

35. The use according to claim 34, wherein the microbial pathogen is a virus, a bacteria, a fungus or a protozoan.

36. The use according to claim 34, wherein the microbial pathogen is a coronavirus or an influenza virus.

37. The use according to claim 34, wherein the microbial pathogen is SARS-CoV-2.

38. A method of controlling odor, comprising operating the system of any one of claims 1 to 13 or 16 to 32.

39. A method of inhibiting growth or distribution of a microbial pathogen, comprising operating the system of any one of claims 1 to 13 or 16 to 32.

40. The method of claim 39, wherein the microbial pathogen is a virus, a bacteria, a fungus or a protozoan.

41. The method of claim 39, wherein the microbial pathogen is a coronavirus or an influenza virus.

42. The method of claim 39, wherein the microbial pathogen is SARS-CoV-2.

Figure 1

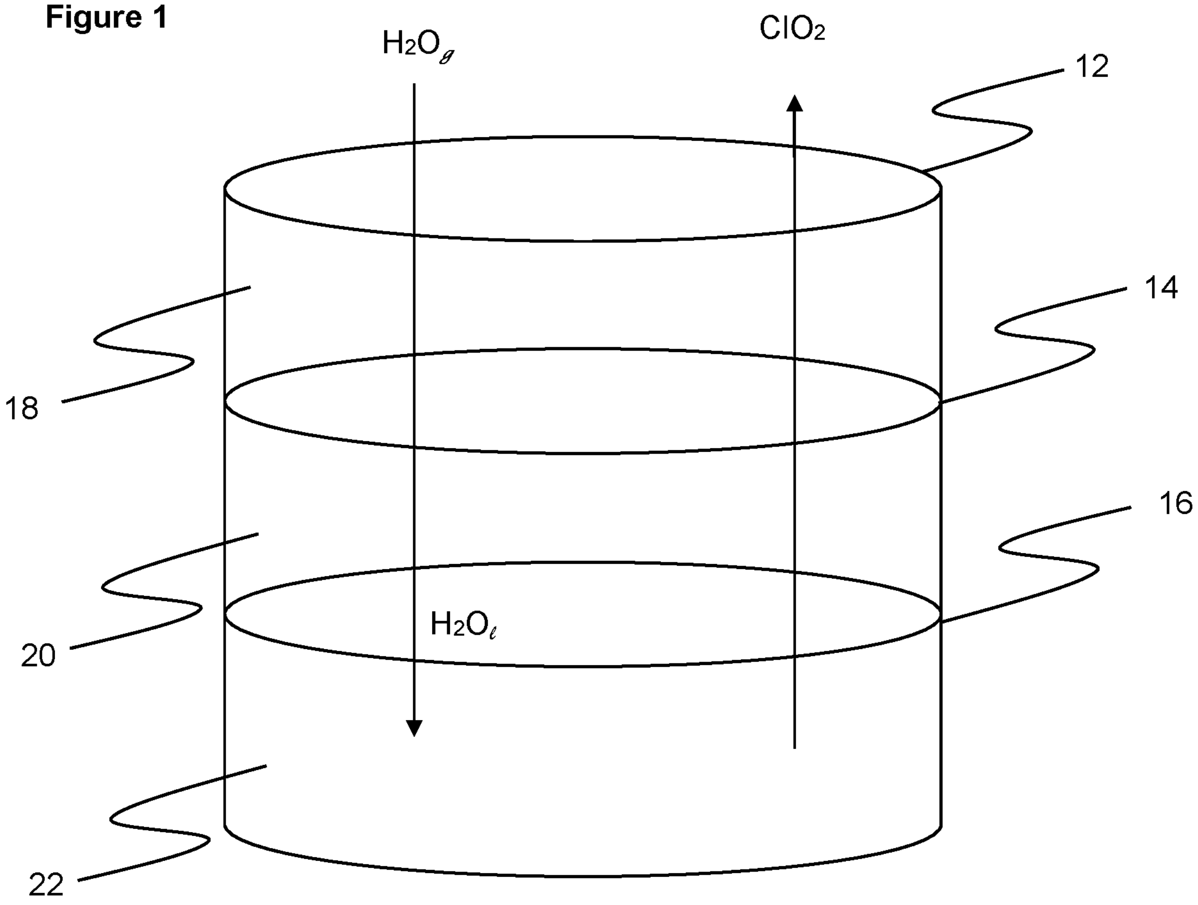
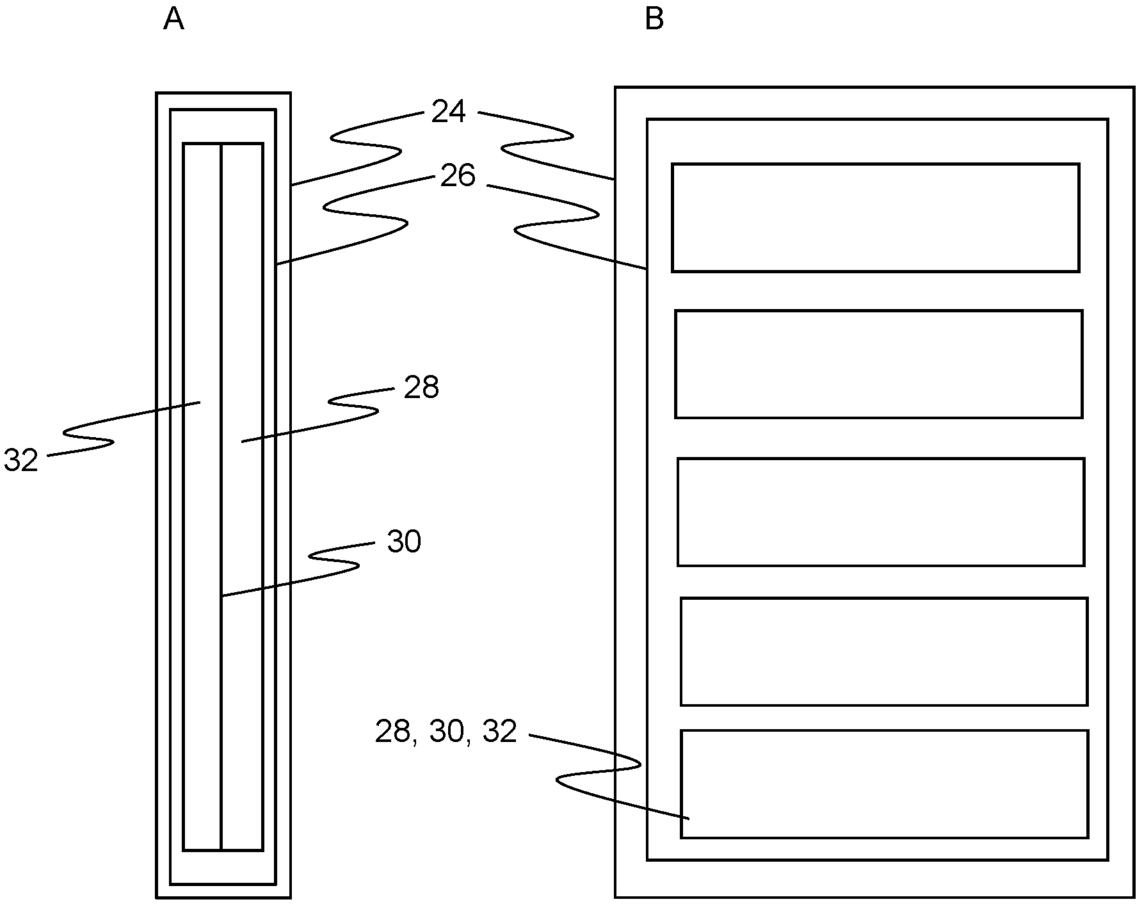


Figure 2



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 21/29469

A. CLASSIFICATION OF SUBJECT MATTER
IPC - A61L 9/12; G05B 15/02; G06F 3/0482 (2021.01)
CPC - A01M 31/00; A61L 9/12; A61L 9/205; A61L 9/22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History document

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015/284249 A1 (Amatera, Inc.) 8 October 2015 (08.10.2015) para [0007]-[0008], para [0016], para [0021], para [0027], para [0031], para [0033], para [0037],	1-5
A	US 2014/113007 A1 (Kato et al.) 24 April 2014 (24.04.2014) entire document	1-5
A	US 7,922,984 B2 (Hamilton et al.) 12 April 2011 (12.04.2011) entire document	1-5
A	US 2006/039840 A1 (Chia et al.) 23 February 2006 (23.02.2006) entire document	1-5
A	US 2006/120945 A1 (Warner et al.) 8 June 2006 (08.06.2006) entire document	1-5
A	US 2017/157904 A1 (Wisconsin Alumni Research Foundation) 8 June 2017 (08.06.2017) entire document	1-5

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

* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"D" document cited by the applicant in the international application	"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
"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)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	"&" document member of the same patent family

Date of the actual completion of the international search 30 June 2021	Date of mailing of the international search report SEP 08 2021
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Kari Rodriquez Telephone No. PCT Helpdesk: 571-272-4300

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 21/29469

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

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

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 6-15, 20-26, and 30-42
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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

This International Searching Authority found multiple inventions in this international application, as follows:
------------------see supplemental box------------------------

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-5

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Bx. III (Lack of Unity)

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid.

Group I: Claims 1-5 is directed toward a sustained chlorine dioxide gas generating system, comprising: a chlorine dioxide gas generation (GG) subsystem, comprising an activator and a chlorite or chlorate reactant in a GG container that is water vapor permeable and chlorine dioxide gas permeable; a relative humidity control (RHC) subsystem, comprising a hygrostatic material that absorbs water vapor above an upper water vapor partial pressure and releases water vapor below a lower water vapor partial pressure, in an RHC container that is water vapor permeable and chlorine dioxide gas permeable; and, a housing that is water vapor permeable and chlorine dioxide gas permeable, the housing containing therein the GG subsystem and the RHC subsystem, wherein the housing permits the ingress of water vapor at an ambient humidity, the RHC subsystem modulates the water vapor partial pressure within the housing, and the housing permits the egress of a chlorine dioxide gas evolved from the GG subsystem by a ClO2 reaction between the activator and the reactant, where the ClO2 reaction is modulated by the water vapor partial pressure within the housing.

Group II: Claims 16-19 is directed toward a distributed chlorine dioxide gas generating system in a defined space, comprising: a chlorine dioxide gas generation (GG) subsystem, comprising an activator, a chlorite or chlorate reactant, and a metered aqueous reaction medium release mechanism; a reaction rate control (RRC) subsystem, comprising one or more chlorine dioxide gas sensors distributed in the defined space, communicating chlorine dioxide gas concentration information to the GG subsystem; and, a control system modulating the metered release of an aqueous GG reaction medium from the metered aqueous reaction medium release mechanism in response the chlorine dioxide gas concentration information provided by the RRC subsystem, wherein the control system thereby modulates desired concentrations of chlorine dioxide gas in the space.

Group III: Claim 27-29 is directed toward a sustained chlorine-dioxide-gas-generating personnel covering system, comprising: a chlorine dioxide gas generation (GG) subsystem, comprising an activator and a chlorite or chlorate reactant in a GG container that is water vapor permeable and chlorine dioxide gas permeable; an anthropogenic humidity control (AHC) subsystem, comprising a desiccant that absorbs water vapor, in an AHC unit that is water vapor permeable and chlorine dioxide gas permeable, the AHC unit enveloping the GG subsystem; and, a personnel covering supporting the GG subsystem enveloped by the AHC unit, the personnel covering being configured to cover a body portion of a wearer while permitting air comprising anthropogenic humidity generated by the wearer to contact the AHC subsystem, the AHC subsystem being configured to modulate water vapor partial pressure within the GG subsystem, the AHC unit being configured to permit the egress of a chlorine dioxide gas evolved from the GG subsystem by a ClO2 reaction between the activator and the reactant, where the ClO2 reaction is modulated by the water vapor partial pressure within the GG subsystem.

The inventions listed as Groups I-III do not relate to a single general inventive concept under PCT Rule 13.1 because, they lack the same or corresponding special technical features for the following reasons:

Special Technical Features:

The invention of Group I includes the special technical feature of a relative humidity control (RHC) subsystem, comprising a hygrostatic material that absorbs water vapor above an upper water vapor partial pressure and releases water vapor below a lower water vapor partial pressure, in an RHC container that is water vapor permeable and chlorine dioxide gas permeable; and, a housing that is water vapor permeable and chlorine dioxide gas permeable, the housing containing therein the GG subsystem and the RHC subsystem, wherein the housing permits the ingress of water vapor at an ambient humidity, the RHC subsystem modulates the water vapor partial pressure within the housing, and the housing permits the egress of a chlorine dioxide gas evolved from the GG subsystem by a ClO2 reaction between the activator and the reactant, where the ClO2 reaction is modulated by the water vapor partial pressure within the housing, not required by Groups II or III.

The invention of Group II includes the special technical feature of a distributed gas generating system in a defined space, comprising: a GG subsystem comprising a metered aqueous reaction medium release mechanism; a reaction rate control (RRC) subsystem, comprising one or more chlorine dioxide gas sensors distributed in the defined space, communicating chlorine dioxide gas concentration information to the GG subsystem; and, a control system modulating the metered release of an aqueous GG reaction medium from the metered aqueous reaction medium release mechanism in response the chlorine dioxide gas concentration information provided by the RRC subsystem, wherein the control system thereby modulates desired concentrations of chlorine dioxide gas in the space, not required by Group I or III.

The invention of Group III includes the special technical feature of gas-generating personnel covering system, comprising: an anthropogenic humidity control (AHC) subsystem, comprising a desiccant that absorbs water vapor, in an AHC unit that is water vapor permeable and chlorine dioxide gas permeable, the AHC unit enveloping the GG subsystem; and, a personnel covering supporting the GG subsystem enveloped by the AHC unit, the personnel covering being configured to cover a body portion of a wearer while permitting air comprising anthropogenic humidity generated by the wearer to contact the AHC subsystem, the AHC subsystem being configured to modulate water vapor partial pressure within the GG subsystem, the AHC unit being configured to permit the egress of a chlorine dioxide gas evolved from the GG subsystem by a ClO2 reaction between the activator and the reactant, where the ClO2 reaction is modulated by the water vapor partial pressure within the GG subsystem, not required by Group I or II.

---Continuation on Supplemental Box---

Bx. III (Lack of Unity)

Shared Technical Features:

The inventions of Groups I and II share the technical features of a chlorine dioxide gas generating system, comprising: a chlorine dioxide gas generation (GG) subsystem, comprising an activator and a chlorite or chlorate reactant.

However, these shared technical features do not represent a contribution over prior art, because the shared technical feature is being anticipated by US 2015/284249 A1 to Amatera, Inc. (hereinafter "Amatera"). Amatera teaches a chlorine dioxide gas generating system (para [0007], an object of the present invention is to provide a chlorine dioxide gas generating agent pack Suitable for being carried to a region where sterilization, disinfection and deodorization are required) comprising: a chlorine dioxide gas generation (GG) subsystem, comprising an activator and a chlorite or chlorate reactant (para [0016], a chlorine dioxide gas generating agent pack 1 according to one embodiment of the invention includes a chlorine dioxide gas generating agent 10 containing a mixture of chlorite powder, gas generation control agent powder, moisture-absorbent powder, water-absorbent resin powder, and activating agent powder; The GG subsystem is the chlorite powder, gas generation control agent powder, and activating agent powder).

The inventions of Groups I and III share the technical feature of a sustained chlorine dioxide gas generating system, comprising: a chlorine dioxide gas generation (GG) subsystem, comprising an activator and a chlorite or chlorate reactant in a GG container that is water vapor permeable and chlorine dioxide gas permeable; a humidity control (HC) subsystem, comprising a material that absorbs water vapor in an HC container that is water vapor permeable and chlorine dioxide gas permeable; wherein the HC subsystem modulates the water vapor partial pressure, and a container permits the egress of a chlorine dioxide gas evolved from the GG subsystem by a ClO2 reaction between the activator and the reactant, where the ClO2 reaction is modulated by the water vapor partial pressure.

However, these shared technical features do not represent a contribution over prior art, because the shared technical feature is being obvious over Amatera. Amatera teaches a sustained chlorine dioxide gas generating system (para [0007], an object of the present invention is to provide a chlorine dioxide gas generating agent pack Suitable for being carried to a region where sterilization, disinfection and deodorization are required; and para [0037], In this way, the chlorine dioxide gas is gradually and continuously generated, and can be continuously released outside through gas-permeable film container 20; If the gas is generated continuously, it is sustained), comprising: a chlorine dioxide gas generation (GG) subsystem, comprising an activator and a chlorite or chlorate reactant (para [0016], a chlorine dioxide gas generating agent pack 1 according to one embodiment of the invention includes a chlorine dioxide gas generating agent 10 containing a mixture of chlorite powder, gas generation control agent powder, moisture-absorbent powder, water-absorbent resin powder, and activating agent powder; The GG subsystem is the chlorite powder, gas generation control agent powder, and activating agent powder) in a housing that is water vapor permeable and chlorine dioxide gas permeable (para [0016], a chlorine dioxide gas generating agent pack 1 according to one embodiment of the invention includes a chlorine dioxide gas generating agent 10 containing a mixture of chlorite powder, gas generation control agent powder, moisture-absorbent powder, water-absorbent resin powder, and activating agent powder; and a gas permeable film container 20 permeable to water vapor and chlorine dioxide gas and containing chlorine dioxide gas generating agent 10. In chlorine dioxide gas generating agent pack 1 according to this embodiment, chlorine dioxide gas generating agent 10 is contained (specifically, sealed) in gas permeable film container 20 permeable to water vapor and chlorine dioxide gas); a humidity control (HC) subsystem, comprising a material that absorbs water vapor (para [0016], a chlorine dioxide gas generating agent pack 1 according to one embodiment of the invention includes a chlorine dioxide gas generating agent 10 containing a mixture of chlorite powder, gas generation control agent powder, moisture-absorbent powder, water-absorbent resin powder, and activating agent powder; and para [0027], The moisture-absorbent powder refers to powder that absorbs the water vapor (humidity)) in an housing that is water vapor permeable and chlorine dioxide gas permeable (para [0016], a chlorine dioxide gas generating agent pack 1 according to one embodiment of the invention includes a chlorine dioxide gas generating agent 10 containing a mixture of chlorite powder, gas generation control agent powder, moisture-absorbent powder, water-absorbent resin powder, and activating agent powder; and a gas permeable film container 20 permeable to water vapor and chlorine dioxide gas and containing chlorine dioxide gas generating agent 10. In chlorine dioxide gas generating agent pack 1 according to this embodiment, chlorine dioxide gas generating agent 10 is contained (specifically, sealed) in gas permeable film container 20 permeable to water vapor and chlorine dioxide gas); wherein the HC subsystem modulates the water vapor partial pressure (para [0027], The moisture-absorbent powder refers to powder that absorbs the water vapor (humidity) in the air through gas-permeable film container 20, and Supplies the moisture to chlorine dioxide gas generating agent 10. The moisture-absorbent powder has the function of causing the chlorine dioxide gas to be produced by the reaction between the chlorite powder and the activating agent powder; If the moisture-absorbent powder, absorbs water vapor to supply it to the gas generating agent, the water vapor partial pressure in the housing is modulated), and a container permits the egress of a chlorine dioxide gas evolved from the GG subsystem by a ClO2 reaction between the activator and the reactant (para [0016] the chlorite powder and the activating agent powder gradually react with each other due to the moisture in the water vapor incorporated into chlorine dioxide gas generating agent 10, so as to gradually produce chlorine dioxide gas. The chlorine dioxide gas produced passes through gas-permeable film container 20 to be released out of chlorine dioxide gas generating agent pack 1), where the ClO2 reaction is modulated by the water vapor partial pressure (para [0016], when water vapor (humidity) in the air passes through gas-permeable film container 20 to be brought into contact with chlorine dioxide gas generating agent 10, the chlorite powder and the activating agent powder gradually react with each other due to the moisture in the water vapor incorporated into chlorine dioxide gas generating agent 10, so as to gradually produce chlorine dioxide gas; and para [0027], The moisture-absorbent powder refers to powder that absorbs the water vapor (humidity) in the air through gas-permeable film container 20, and Supplies the moisture to chlorine dioxide gas generating agent 10. The moisture-absorbent powder has the function of causing the chlorine dioxide gas to be produced by the reaction between the chlorite powder and the activating agent powder; If the moisture-absorbent powder causes the reaction to occur, the ClO2 reaction is modulated by the water vapor partial pressure)...

--Continued on Supplemental Box------------------------------

Bx. III (Lack of Unity)

However, Amatera does not teach the system wherein the GG subsystem is provided in its own GG container that is water vapor permeable and chlorine dioxide gas permeable; wherein the HC subsystem is provided in an HC container that is water vapor permeable and chlorine dioxide gas permeable. It would have been obvious to one of ordinary skill in the art to provide the GG subsystem and the HC subsystem in separate containers because the amount of water absorbent material in the HC subsystem can be adjusted to optimize the amount of moisture supplied to the GG subsystem, and further, the material of the HC container can be selected with an optimal water vapor permeablilty to provide the moisture to the GG subsystem, thereby providing the user more control over the rate of the reaction and the amount of ClO2 produced. Further, it would have been obvious to one of ordinary skill in the art to provide the GG subsystem and HC subsystem in containers that are water vapor permeable and chlorine dioxide gas permeable because the flow of water vapor and ClO2 is necessary for the operation of the device, and further the housing which contains both is water vapor permeable and chlorine dioxide gas permeable (para [0016], In chlorine dioxide gas generating agent pack 1 according to this embodiment, chlorine dioxide gas generating agent 10 is contained (specifically, sealed) in gas permeable film container 20 permeable to water vapor and chlorine dioxide gas).

The inventions of Groups I and III share the technical features of a chlorine dioxide gas generating system, comprising: a chlorine dioxide gas generation (GG) subsystem, comprising an activator and a chlorite or chlorate reactant.

However, these shared technical features do not represent a contribution over prior art, because the shared technical feature is being anticipated by Amatera. Amatera teaches a chlorine dioxide gas generating system (para [0007], an object of the present invention is to provide a chlorine dioxide gas generating agent pack Suitable for being carried to a region where sterilization, disinfection and deodorization are required) comprising: a chlorine dioxide gas generation (GG) subsystem, comprising an activator and a chlorite or chlorate reactant (para [0016], a chlorine dioxide gas generating agent pack 1 according to one embodiment of the invention includes a chlorine dioxide gas generating agent 10 containing a mixture of chlorite powder, gas generation control agent powder, moisture-absorbent powder, water-absorbent resin powder, and activating agent powder; The GG subsystem is the chlorite powder, gas generation control agent powder, and activating agent powder).

As the common features were known in the art at the time of the invention, they cannot be considered special technical features that would otherwise unify the groups.

Therefore, Groups I-III lack unity under PCT Rule 13 because they do not share a same or corresponding special technical feature.

Note: Claims 6-15, 20-26, and 30-42 are unsearchable because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).