Title: "Microchip Pathogen Sensor & Advanced Ozone Generation Integration for COVID-19 Detection and Disinfection Applications"

Authors:
Thomas James Douglas Murphy, Western Cape, South Africa, thomas@waterlife.systems;
Jamie Gordy, British Columbia, Canada, jamie@waterlife.systems

Corresponding Author:
Thomas Murphy
38 Canterbury St
Zonnebloem, Cape Town, Western Cape, South Africa 8001

Abstract: Ozone is a powerful oxidant that can be tamed through programmable treatment techniques, at both a micro and macro scale, to provide a wide range of applications. One such application facilitates the multiple-use functionality of bioelectrical Microchip Pathogen Sensors that can detect COVID-19 in virtual real-time, in both air and liquid channels. In-solution ozone generation reduces system design components and cost. Previous work fails to consider advanced liquid ozone generation as an economically competitive COVID-19 disinfectant for healthcare facilities and the Built Environment in totality. The Advanced Ozone Generation techniques also allow the customization of ozone output levels based on water contaminants, i.e. bromide and iodide. Considering civil infrastructure only from the centralized standpoint misses the opportunity to add significant resiliency, especially for water wise population centers. The key impact of this paper is to explain the development of pathogen sensors and disinfection techniques for distributed integration into the Built Environment. The information below will provide a wide range of COVID-19 response personnel with the justification to proactively integrate distributed Microchip Pathogen Sensors and Advanced Ozone Generation systems into centralized infrastructure for greater resiliency and sustainability of core human life support systems.

Keywords: Advanced Ozone Generation, COVID-19 Detection, Disinfection, Wastewater

Acronyms:
<u>Internet of Things (IoT)</u> – a system of interrelated computing devices, mechanical and digital machines provided with the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction
<u>Microchip Pathogen Sensors (MPS)</u> – Microchip sized digital pathogen sensors that identify pathogens in liquid or air, in real-time, by species
<u>Advanced Ozone Generation (AOG)</u> – In-solution ozone generators that are programable to remove target pollutants
<u>Distributed Sanitation and Water Supply Systems (DSWSS)</u> –sanitation and drinking water supply systems that 1) do not necessarily connect to a networked sewer or water supply system and 2) collect, convey, and fully treat the specific input, to allow for safe reuse or disposal of the generated output
<u>ISO 30500</u> – International Organization for Standardization's general safety and performance requirements for design and testing of Non-sewered sanitation systems — Prefabricated integrated treatment units

INTRODUCTION

The goal of this paper is to provide wastewater treatment professionals, healthcare industry, urban planners, and other pandemic related prevention and response interests with the justification to proactively integrate distributed microchip bioelectrical sensors into the built environment. Sensors are outfitted with Internet of Things (IoT) networking via mobile Wi-Fi or satellite communications for air and liquid pathogen detection in centralized and decentralized wastewater treatment systems, and other distributed applications such as wearables and sensor integration throughout the built environment. A secondary goal is to promote the use of in-solution ozone generation systems, that at the micro level facilitate the multiple-use functionality of the microchip bioelectrical sensors, and onsite ozone generation for decentralized wastewater and drinking water treatment systems at the macro level that provide disinfection of potential pathogens to prevent further distribution or exposure to humans.

The global systemic risks associated with the COVID-19 pandemic and rapid global urbanization (Desai 2020), as well as lack of freshwater due to climate change and overpopulation in the areas that WASH programs operate (McNabb 2019), present a variety of human existential challenges. From emerging pollutant discharge into aquatic systems (Patel *et al.* 2020), resource competition historically leading to war (Levy 2019), rain in the remote mountain regions of the world that supply major populations with water containing man-made plastic particles (Zhang *et al.* 2019), to carcinogenic “forever chemicals” being discharged by industry into human drinking water supply (Lim 2019), the challenges fundamentally involve freshwater supply and wastewater treatment infrastructure (Jahn *et al.* 2019). COVID-19 and the reality of worldwide pandemic outbreaks are set to financially stress centralized water utilities throughout the world to failure, and funding is likely to be diverted from water and sanitation improvement and service expansion projects in the years to come (Cheval *et al.* 2020).

Urban populations are most susceptible to pathogen spread in part due to interconnected infrastructure and population density (Connolly *et al.* 2020). From the wastewater treatment standpoint, fecal transmission pathways via the aerosolization of liquid waste are now known to transmit COVID-19, with a virus survival timeline in water and sewage between numerous days and weeks (Ghernaout *et al.* 2020). Aerosolization of human excrement can take place at any point of the wastewater service chain, such as during the flush of a toilet or in pipeline leaks.

METHODS

Various sources of primary literature were examined using Google Scholar, Thomson Reuters and Scopus have provided a plethora of information. As presented in the following sections of this argument, the support for formed ideas consists of a collection of perspectives, information, and studies formed and published primarily during the progression of the COVID-19 pandemic, chosen for their clear illustration of environmental, urban and public health issues. For full disclosure, author Thomas Murphy is President of Water Life Systems Inc, and Jamie Gordy CEO of Water Life Systems Inc, a USA corporation with Canadian, South African, and other international operations that holds Intellectual Property Ownership Rights to hardware and software components and integrated systems including, but not limited to, groundwater, surface water, and wastewater treatment, resource and nutrient recovery, and remote digital sensors and monitoring systems.

DISTRIBUTED BUILT ENVIRONMENT COVID-19 SOLUTIONS

As a solution to accommodate rapid population growth and climate change in the presence of COVID-19 and future potential pandemics, previous work has not adequately considered the comprehensive integration of 1. Distributed IoT connected Microchip Pathogen Sensors (MPS) customized to detect COVID-19 and other target water and air bourne pathogens throughout the built environment, with washroom facilities as a priority; and 2. Advanced Ozone Generation (AOG) to optimally disinfect wastewater in a variety of applications, including 3. Distributed Sanitation and Water Supply Systems (DSWSS) that utilize ozone in a primary wastewater treatment process that produces zero sludge and no toxic effluents, and provides a potable, or any pre-defined, quality water supply sourced by either the treated wastewater or another ground, surface, or municipal water source in a grid based closed-loop plumbing configuration.

MICROCHIP PATHOGEN SENSORS

Distributed measurements will alleviate public interaction concerns and provide global societies to find a "new normal" that is reflective of the "old normal". Water Life Systems Inc., along with a university partner in British Columbia, Canada, have developed a multiple use bioelectrical sensor with mobile WiFi or satellite communications capabilities. The sensor can be applied to air and water borne pathogen detection. Built infrastructure applications are extensive and can include public/shared/private toilet bowl and washroom integration, building entrances and pedestrian throughways, public transportation vehicles and facilities, wearables for frontline emergency personnel, and distributed wastewater infrastructure applications.

A primary goal is to immediately and as accurately as possible detect a potential pandemic inducing pathogen species before it is distributed throughout centralized drinking water and wastewater systems, especially where the concentration of residual disinfectant is a norm. It is a common understanding that bacteria in biofilms enter individual homes, such as with distribution of legionella. Showerheads, sink taps, and toilets provide the sources of aerosolization to distribute COVID-19-containing water droplets. The development of a distributed network of mobile SARS-CoV2 and other pathogen detection systems that can be exposed to various environments is critical to quickly trace and confirm suspected cases, as well as asymptomatic infected cases without costly centralized laboratories (Bhalla *et al.* 2020).

ADVANCED OZONE GENERATION

Figure 1 provides a comparison of various disinfectant techniques.

Figure 1 – Disinfectant Comparison			
Disinfectant	Description	Advantages	Limitations
Chlorination (Gas)	At normal pressures, elemental chlorine is a toxic, yellow-green gas, and is liquid at high pressures.	Chlorine is very effective for removing almost all microbial pathogens and is appropriate as both a primary and secondary disinfectant.	Chlorine is a dangerous gas that is lethal at concentrations as low as 0.1 percent air by volume. There is a resistance build up by some bacteria/virus.

Chlorination (Sodium-hypochlorite solution)	Sodium-hypochlorite is more expensive than chlorine gas.	Sodium hypochlorite is easier to handle than gaseous chlorine or calcium hypochlorite.	Sodium hypochlorite is very corrosive. Hypo-chlorite solutions decompose quickly. There is a resistance build-up by some bacteria/virus.
Chlorination (Solid-calcium hypochlorite)	Calcium hypochlorite is a white solid that contains 65 percent available chlorine and dissolves easily in water.	ADVANTAGES When packaged, calcium hypochlorite is very stable, allowing a year's supply to be stored.	Calcium hypochlorite is a corrosive material with a strong odor that requires proper handling. Reactions between calcium hypochlorite and organic material can generate enough heat to cause a fire or explosion. There is a resistance build-up by some bacteria/virus bought at one time.
Chloramine	Chloramines are formed when water containing ammonia is chlorinated or when ammonia is added to water containing chlorine (hypochlorite or hypochlorous acid).	An effective bactericide that produces fewer disinfection by-products, chloramine is generated onsite. Usually, chloramine-forming reactions are 99 percent complete within a few minutes.	Chloramine is a weak disinfectant. It is much-less effective against viruses or protozoa than free chlorine. Chloramine is appropriate for use as a secondary disinfectant to prevent bacterial regrowth in a distribution system. Nitrogen trichloride appears to be the only detrimental reaction. It may be harmful to humans and imparts a disagreeable taste and odor to the water. There is a resistance build-up by some bacteria/virus
Ozonation	Ozone, an allotrope of oxygen having three atoms to each molecule.	**Ozone is the most powerful oxidizing and disinfecting agent** practically available. **Requires the shortest contact time and lowest dosage of all. Ozone leaves no residual toxins, flavors or**	Ozone gas is unstable and must be generated onsite.

		chemicals and there is no resistance possible by any bacteria/virus. It also **does not produce halogenated organic materials** unless a bromide ion is present when used in combination, which is neutralized with real-time systems monitoring and generation level alterations.	
Ultraviolet Light (UV)	Ultraviolet (UV) radiation is generated by a special lamp. When it penetrates the cell wall of an organism, the cell's genetic material is disrupted, and the cell is unable to reproduce.	UV radiation effectively destroys some bacteria and viruses. A secondary disinfectant must be used to prevent regrowth of micro-organisms. UV radiation can be attractive as a primary disinfectant for small systems.	UV radiation may not inactivate Giardia lamblia or Cryptosporidium cysts and should be used only by ground water systems not directly influenced by surface water—where there is virtually no risk of protozoan cyst contamination. UV radiation is unsuitable for water with high levels of suspended solids, turbidity, color, or soluble organic matter. These materials can react with or absorb the UV radiation, reducing the disinfection performance.
Source: National Drinking Water Clearinghouse; Kabanova 2015.			

There are many advantages to utilizing ozone in water and wastewater treatment, including ozone's effectiveness over a varied pH range; instantaneously reactive with pathogens and has stronger germicidal properties than chlorination; immense oxidizing power with a short reaction time; no chemicals added to the water in the treatment process; and the elimination of a wide variety of inorganic, organic and microbiological elements, and taste and odor problems. Figure 2 shows some commonly cited disadvantages to utilizing Ozone in water and wastewater treatment. These challenges are overcome with new advanced in-solution and programmable ozone generation and treatment techniques, such as the customization of ozone output levels based on water contaminants, i.e. bromide and iodide. AOG systems have been developed along with the progression of low-cost digital water quality and quantity sensor development. They exist on the "micro" scale, to cleanse the bioelectrical microchip measurement locations for multiple use and long-term measurement functionality, as well as on a scalable "macro" scale to provide appropriate ozone generation for primary and subsequent wastewater treatment applications.

Figure 2 – How Commonly Cited Ozone Disadvantages Are Overcome

Disadvantage	How AOGS Overcome
1. Higher equipment and operational costs, difficult to find support for system maintenance.	Systems design is engineered with fewer components at a reduced cost, as well as the ability to easily swap out parts with limited operational lifetime. Any electrician or plumber can service systems with minimal training.
2. Ozonation provides no residual to inhibit or prevent regrowth.	The distributed deployment capabilities of the scalable in-solution generation systems, coupled with the pathogen and other sensors, allows real-time monitoring and on demand treatment of water in a grid-configured plumbing infrastructure layout.
3. Ozonation by-products are still being evaluated and it is possible that some by-products by be carcinogenic. These may include brominated by-products, aldehydes, ketones, and carboxylic acids. This is one reason that the post-filtration system may include an activate carbon filter.	The programmability and sensor integration into the ozone generation process always allows the solution and discharge to be custom configured and monitored. The post ozone treatment can include filters to customize mineral content and taste.
4. The system may require pretreatment for hardness reduction or the addition of polyphosphate to prevent the formation of carbonate scale.	Currently operating industrial grade in-solution ozone generators that are in hard water applications do not exhibit scaling of any sort.
5. Ozone is less soluble in water, compared to chlorine, and, therefore, special mixing techniques are needed.	The ozone is generated in an aqueous solution and requires no further mixing.
6. Potential fire hazards and toxicity issues associated with ozone generation.	The system design is not comprised of external oxygen tanks or other fire hazards beyond the electrical power supply, and toxicity issues are negotiated through programmability and sensor integration as previously mentioned.

(Jiao Wang, *et al.* 2020) and (von Gunten, 2003) illustrate commonly held outdated misconceptions about the use of ozone in healthcare industry wastewater and drinking water treatment. Additionally, (Ding, *et al.* 2019) illustrates the benefits of utilizing ozone as a disinfectant, as some species of bacteria are evolving resistance to chlorine disinfection. Ozone also provides a safe an effective dual liquid-air disinfectant role compared to chlorine, bleach, and most other disinfectants (Dubuis, 2020). The ozone generation techniques that utilize aqueous in-solution generation and programmability via digital sensor technologies put to rest the challenges of utilizing ozone in water and wastewater treatment systems. The use and maintenance of AOG is analogous to smart phones, where models can be produced at an affordable price, and system design facilitates easy maintenance that can be performed by any electrician or plumber trained for the system.

DISTRIBUTED SANITATION AND WATER SUPPLY

This distributed infrastructure offers both rural and urban populations the flexibility to quickly reorganize and adapt to today's existential challenges, i.e. create more sustainable and resilient living systems (Voutchkov 2019; Hutton *et al.* 2007; Cameron *et al.* 2019). Governmental authorities of various levels throughout the world are now legislating centralized and distributed wastewater treatment derived resource reuse, emerging pollutant removal at the point of waterway and centralized system entry, and to combat an ongoing lack of sufficient wastewater treatment and water supply infrastructure (Earl *et al.* 2019; Ghernaout *et al.* 2019; Kehrein *et al.* 2020).

The optimally designed DSWSS utilize a sanitation system with ISO 30500 specs, and remote digital monitoring capabilities for the monitoring and operational benefits that are associated with IoT connectivity and Big Data analysis. IoT management systems provide significant asset operational and maintenance cost savings. Water, energy, and pathogen parameters are all digitally monitored, and can be centrally integrated for organizational and regulatory compliance. Blockchain technologies can provide personal data protection in the case of distributed sensors deployed throughout the built environment (Kim *et al.* 2019).

CONCLUSIONS

The ethical concerns of MPS technology integration into the built environment can be alleviated with the integration of Blockchain technologies. MPS and AOG integrated solutions enable rapid and on-site detection and disinfection of viruses for Built Environment point-of-care diagnosis, onsite disinfection, and to prevent and manage epidemics at an early stage. Ozone is extremely active as a disinfectant, and because of its disadvantages like instability, high capital cost and high operating costs being surmounted with AOG and MPS integrated technologies, its utilization in water and wastewater treatment will significantly expand.

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