Can We Use Adenovirus Validated Ultraviolet Systems for Inactivation of SARS-CoV-2, The Virus That Causes COVID-19?

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ABSTRACT: Ultraviolet (UV) technology is a physical process for disinfection by exposing bacteria, viruses and protozoa to UV light, rendering them incapable of reproducing or further affecting water supplies. Pathogenic viruses such as adenovirus, norovirus, rotavirus, and hepatitis A commonly occur in both surface and groundwater sources. This paper discusses evidence for SARS-CoV-2 (the virus that causes COVID-19) in water and the possibility of using UV systems for its disinfection, providing information regarding the ability of a UV system validated to a 4-log virus inactivation per the U.S. EPA guidelines with adenovirus to effectively mitigate SARS-CoV-2 in water.

INTRODUCTION

Ultraviolet (UV) technology is a physical process for disinfection by exposing bacteria, viruses and protozoa to UV light, rendering them incapable of reproducing or further affecting water supplies. Pathogenic viruses such as adenovirus, norovirus, rotavirus, and hepatitis A commonly occur in both surface and groundwater sources [1]–[3]. Disinfection of viruses in water by common methods such as chlorine, chlorine dioxide, filtration, or ozonation, is challenging; however, UV can offer effective inactivation [4]. Here we discuss some evidence for SARS-CoV-2 (the virus that causes COVID-19) in water and the possibility of using UV systems for its disinfection.

VIRAL INACTIVATION WITH UV

Viruses are composed of a nucleic acid (DNA or RNA; double-stranded or single-stranded) encased in a protein capsid, which in some viruses is encased in a lipid envelope. In all cases, the virus surface contains a proteinaceous receptor, which is necessary for binding to and entering the host cell. The sensitivity of a virus to UV irradiation can be roughly predicted according to its basic features. Lipid enveloped viruses are generally more sensitive to environmental stress, including UV than their non-enveloped counterparts [5].

The type of nucleic acid may also play a role in UV sensitivity. For example, single-stranded RNA (ssRNA) viruses tend to be more sensitive than double-stranded DNA (dsDNA) viruses [6]. This is due to the stability of the double-stranded structure, and the lack of a repair mechanism in most RNA viruses [7].

The most familiar mechanism for virus inactivation by UV is the direct damage to the nucleic acid, due to the generation of pyrimidine dimers by the UV irradiation. In some cases, however, viruses may recover from DNA damage by applying a repair mechanism [7]. A wavelength of approximately 260 nanometers (nm), such as emitted from monochromatic low pressure (LP) UV lamps, is effective at generating pyrimidine dimers, thus the repair mechanism can increase the virus resistance to such UV inactivation. However, polychromatic UV systems (e.g., MP, 200-415 nm) inactivate microorganisms by damaging both DNA and proteins [8] and generating oxygen radicals [9]. This results in a virus that is unable to enter the host; a feat unachievable by monochromatic LP lamps.

Atlantium's medium pressure (MP) Hydro-Optic™ (HOD) UV technology was validated for 4-log virus inactivation, per the U.S. EPA guidelines, using real adenovirus. This virus was chosen as a base for the U.S. EPA strict regulatory criteria of 4-log (99.99%) virus inactivation because adenoviruses, currently thought to be the most UV-resistant class of viruses, are used as the gold standard for viral inactivation requirements and the determination of biosecurity. The validated HOD UV solution has been proven in municipal, bottled water and other commercial applications since 2010.

Figure 1: Hydro-Optic™ (HOD) UV validated to U.S. EPA guidelines for 4-log virus inactivation using real adenovirus, not a surrogate.

ADENOVIRUS AND SARS CoV-2

Adenovirus and coronavirus (SARS-CoV-2) are very different from each other in terms of virion properties that are important for UV sensitivity (Table 1). SARS CoV-2 is enveloped and has a single-stranded RNA genome, while adenovirus has a more stable dsDNA genome and is non-enveloped. The two viruses are similar to each other in terms of large genome and virion size. Large genomes are not rare for DNA viruses (the adenovirus) but they are not often common in RNA viruses. A large RNA genome is likely to require a repair mechanism for nucleic acid replication.

Table 1: Comparison of Basic Virion Properties of Adenoviridae and Coronaviridae Families

	Adenoviridae	Coronaviridae
Genome size (kb)	35-36	27-32
Envelope	Non-enveloped	Enveloped
Virion size (nm)	90	120
Nucleic acid	dsDNA	ssRNA (+)

SARS-CoV-2 MECHANISM OF TRANSMISSION

The main route of SARS-CoV-2 transmission is person-to-person by aerosols. It is also known that fomites (aerosol contaminated surfaces) have some contribution to transmission [10]. However, recent information suggests that SAR-CoV-2 may be transmitted through the fecal-oral route as well [11].

Although it is not yet clear how SARS-CoV-2 infection transmits from feces and urine, a previous study on SARS-CoV-2 demonstrated survival and infectivity of the viruses in feces and urine up to 96 and 72h respectively, and in water up to 72h [12]. This further emphasizes the need to reexamine the risk analysis to water safety from SARS-CoV-2.

INACTIVATION OF SARS-CoV-2 BY UV

Testing a pathogen of an ongoing pandemic such as the SARS-CoV-2 may be difficult due to the required biosafety level (BSL) precautions. As a result, it is common practice to use related viral species as a reference to high BSL species. A surrogate species should have a similar response to UV treatment[1]. In addition, since SARS-CoV-2 is still not well studied and its mechanism of transmission not fully known, reliance on a surrogate species becomes important when determining the efficacy of UV to treat the virus.

The coronaviridae family is composed of several genera, with all human pathogens belonging to the same genus (betacoronovirus). Several studies have been published detailing SARS inactivation by monochromatic UV (mainly 254 nm). While the standard dose typically applied for inactivation of pathogens is approximately 40 [13] to 60 mJ/cm^2, further studies indicate that the required UV dose is closer to 100 mJ/cm^2 or even as high as 200 mJ/cm^2 to achieve 4-log inactivation [12], [14], [15], making it safe to estimate that SARS-CoV-2 will have the same UV sensitivity, i.e., a UV dose of 100 to 200 mJ/cm^2 will be needed to achieve 4-log inactivation of SARS-CoV-2[2].

This point was emphasized in a March 12, 2020, "Coronavirus Research Update" webcast hosted by the Water Research Foundation (WRF), where Dr. Mark Sobsey[3] of the Gillings Schools of Global Public Health, University of North Carolina Chapel Hill commented on what is known about SARS-CoV-2 UV inactivation. Dr. Sobsey stated, "We actually have a little bit of data on UV inactivation of some other coronaviruses, and again, they can be inactivated with UV. Data that is available suggests that they are relatively persistent to UV, probably somewhere in between adenoviruses and others that are less resistant than adenoviruses, but certainly not more than adenoviruses. Depending on the design criteria and dosing criteria for UV systems, current UV systems that can inactivate adenoviruses should be fine for a virus like this, based on the other coronaviruses. UV should be effective."

SUMMARY

When faced with a pandemic such as SARS-CoV-2, timely risk assessment and action are required to prevent the spread of the virus. Additionally, these circumstances highlight the importance of water and wastewater treatment facilities to consider enhancing their treatment processes to provide continuous and permanent virus control. A validated UV technology, such as the Atlantium's HOD UV with 4-log virus inactivation is a viable non-chemical treatment option for utilities and commercial facilities looking to protect their water sources from SARS-CoV-2. UV provides inactivation of SARS-CoV-2 without the reliance on chemical disinfectants and their associated risks (e.g., safety, storage, chain of supply, handling, and formation of carcinogenic disinfection byproducts).

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SOURCES

[1] For example, EPA funded studies for adenovirus inactivation by UV used three different species; all three had similar UV sensitivity.

[2] All UV doses in this paragraph are based on monochromatic UV (LP).

[3] Mark Sobsey was a leading researcher on an EPA study (EPA Grant Number R829012) of UV inactivation of adenovirus and many other microbial species.

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