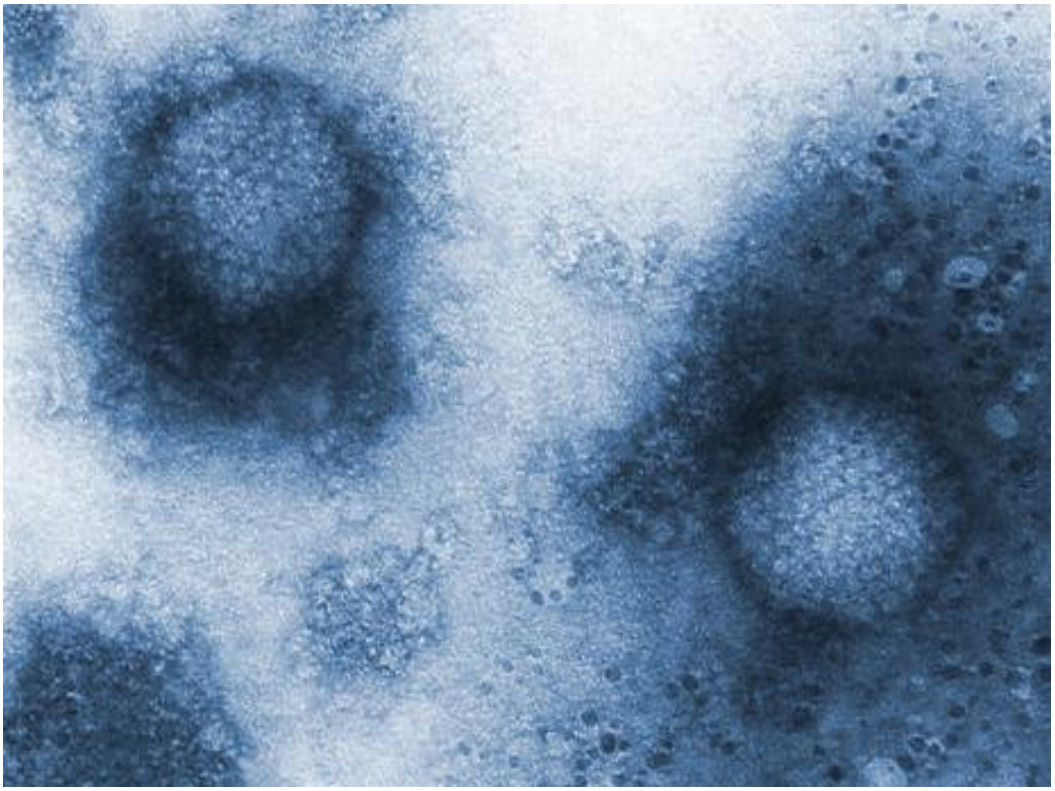
April 28th, 2022

Adenovirus Ultraviolet Susceptibility and Epidemiology



Background

Human adenovirus infections are a significant source of morbidity and mortality, world-wide and at all ages, through highly transmittable infections at mucosal sites, including the eyes, the respiratory tract, and the urinary and gastrointestinal tracts. Adenoviruses can cause a variety of infections and diseases and they include over fifty serotypes known to infect humans. Adenoviruses are medium-sized (90-100 nm), nonenveloped icosahedral viruses containing double-stranded DNA ranging from around 30-40 kb in length depending on the serotypes (Eischeid 2011). Adenoviruses belong to the family of Adenoviridae and the virus consists of a protein capsid surrounding a viral core comprised of both the dsDNA genome and proteins. The image on page 1 shows two adenovirus type 2 virions showing the capsomeres, which are hexagonal shaped and which comprise the outer covering known as a capsid. These adenoviruses displayed an icosahedral symmetry, meaning the shape has 12 vertices and 20 facets (*Image reprinted courtesy of CDC*).

Adenovirus Epidemiology and Pathogenicity

Adenoviruses can be transmitted via the respiratory route or the fecal-oral route. They can cause respiratory infections, severe dysentery, eye infections, or urinary tract infections. Adenoviral infections are often acute in their onset and can cause asymptomatic, self-limiting, severe, or even fatal outcomes. Infected hosts can shed the virus for up to several years, especially in asymptomatic cases. This characteristic is problematic, especially when the host is unaware of the infection or it is not severe, because it can become widespread throughout populations. People who are typically at risk for more severe infections include the immunocompromised, infants, and young children. Among the immunocompromised population, the adenoviral fatality rate can reach 50%.

Adenovirus is a leading cause of gastroenteritis in children. It has caused respiratory infection epidemics in military barracks and boarding schools. Although adenoviral infections are typically self-limiting in healthy adults, the virus poses a significant threat as shown by severe cases of pneumonia (Eischeid 2011; USEPA 2006).

Human adenoviruses (HAdV) are grouped into six groups (A-F). Group F holds serotypes 40 and 41 which are considered to be enteric adenoviruses (fecal-oral route) as they can result in severe diarrhea causing as much as 20% of diarrhea-related hospitalizations in the developed world and are a leading cause of infant mortality in developing nations.

Adenoviruses may persist in human tonsils and were first isolated from human adenoids. It is not known whether adenoviruses or their genomes can persist in other human organ systems. When the adenoids are removed during acute adenovirus infection, intact viral genomes are present.

Adenoviruses most commonly cause respiratory illness; however, depending on the infecting serotype, they may also cause various other illnesses, such as gastroenteritis, conjunctivitis, cystitis, and rash-associated illnesses. Symptoms of respiratory illness caused by adenovirus infection range from the common cold syndrome to pneumonia, croup, and bronchitis. See Table 1 for a summary of symptoms by serotype.

Adenovirus has been identified in both raw sewage throughout the world and some treated wastewaters (Crabtree 1997). The virus can spread via ingestion or exposure to contaminated waters and it has been detected in polluted waters (Yates 2006; USEPA 2006). Adenovirus has also been implicated in several outbreaks at swimming pools or ponds where it has resulted in conjunctivitis symptoms.

Adenoviruses usually spread from infected people to others through close personal contact such as touching or shaking hands, via the airborne route from coughing and sneezing, and by touching objects or surfaces with adenoviruses on them then touching your mouth, nose, or eyes. Ingestion by fecal-oral transmission and by waterborne transmission is also possible. Adenoviruses are not seasonal and can cause illness in people of all ages any time of year. Some serotypes are capable of establishing persistent asymptomatic infections in tonsils, adenoids, and intestines of infected hosts, and shedding can occur for months or years. Other types cause sporadic infection and occasional outbreaks. Epidemics of febrile disease with conjunctivitis are associated with waterborne transmission of some adenovirus types.

Table 1: Adenovirus Symptoms and Epidemiology by Type

Serotype	Common Symptom	Notes
Adenovirus Type 1	Acute gastroenteritis, Childhood febrile illness and pharyngoconjunctival fever, Pneumonia and other acute respiratory illnesses, Pertussis-like illness, Conjunctivitis, Upper respiratory illness and hepatitis	Second most frequent in children, Endemic in some locations, Usually acquired in childhood
Adenovirus Type 2	Acute Respiratory Illness, Childhood febrile illness and pharyngoconjunctival fever, Pneumonia and other acute respiratory illnesses, Pertussis-like illness, Conjunctivitis, Upper respiratory illness and hepatitis	Most common Adenovirus in children, Endemic in some locations, high prevalence, Usually acquired in childhood
Adenovirus Type 3	Acute Respiratory Illness, Childhood febrile illness and pharyngoconjunctival fever, Pneumonia and other acute respiratory illnesses, Pertussis-like illness, Conjunctivitis, Keratoconjunctivitis, Upper respiratory illness and hepatitis, Lower respiratory illness	Third most frequently found adenovirus in children
Adenovirus Type 4	Acute Respiratory Illness, febrile disease & conjunctivitis, Conjunctivitis, Lower respiratory illness	Spreads in water, vaccine available
Adenovirus Type 5	Acute Respiratory Illness, Childhood febrile illness and pharyngoconjunctival fever, Pneumonia and other acute respiratory illnesses, Pertussis-like illness, Conjunctivitis, Upper respiratory illness and hepatitis	The most common Adenovirus infection,fourth most common in children, Endemic in some locations, high prevalence, Usually acquired in childhood
Adenovirus Type 6	Tonsil infection	Endemic in some locations, Usually acquired in childhood, sixth most common Adenovirus found in children
Adenovirus Type 7	Acute Respiratory Illness, febrile disease & conjunctivitis, Childhood febrile illness and pharyngoconjunctival fever, Pneumonia and other acute respiratory illnesses, Conjunctivitis, Lower respiratory illness	Severe illness, fatalities possible, fifth most common Adenovirus found in children, vaccine available
Adenovirus Type 8	Keratoconjunctivitis, Conjunctivitis	May cause epidemic outbreaks
Adenovirus Type 9	Keratoconjunctivitis	
Adenovirus Type 11	Acute hemorrhagic cystitis	
Adenovirus Type 14	Acute Respiratory Illness, Pneumonia and other acute respiratory illnesses	
Adenovirus Type 19	Keratoconjunctivitis, Pertussis-like illness, Conjunctivitis	May cause epidemic outbreaks
Adenovirus Type 21	Pertussis-like illness, Conjunctivitis, Lower respiratory illness	
Adenovirus Type 37	Keratoconjunctivitis	May cause epidemic outbreaks
Adenovirus Type 53	Keratoconjunctivitis	May cause epidemic outbreaks
Adenovirus Type 54	Keratoconjunctivitis	May cause epidemic outbreaks
Adenovirus Type 55	Acute respiratory disease	Variable severity
Adenovirus Type 40	Gastroenteritis, diarrhea, (hepatitis?)	Affects children, fatalities possible
Adenovirus Type 41	Gastroenteritis, diarrhea, (hepatitis?)	Affects children, fatalities possible

For some adenovirus serotypes, the clinical spectrum of disease associated with infection varies depending on the site of infection. Infection with adenovirus 7 acquired by inhalation is associated with severe lower respiratory tract disease, whereas oral transmission of the virus typically causes no or mild disease.

There is a vaccine for adenovirus types 4 and 7 that is used in military personnel who may be at higher risk for infection from these two adenovirus types. There is currently no adenovirus vaccine available to the general public. Adenoviruses are resistant to chemical or physical agents and can survive for prolonged periods outside of the body of a host. Adenoviruses can persist in the indoor environment for up to 3 months (Kramer 2006).

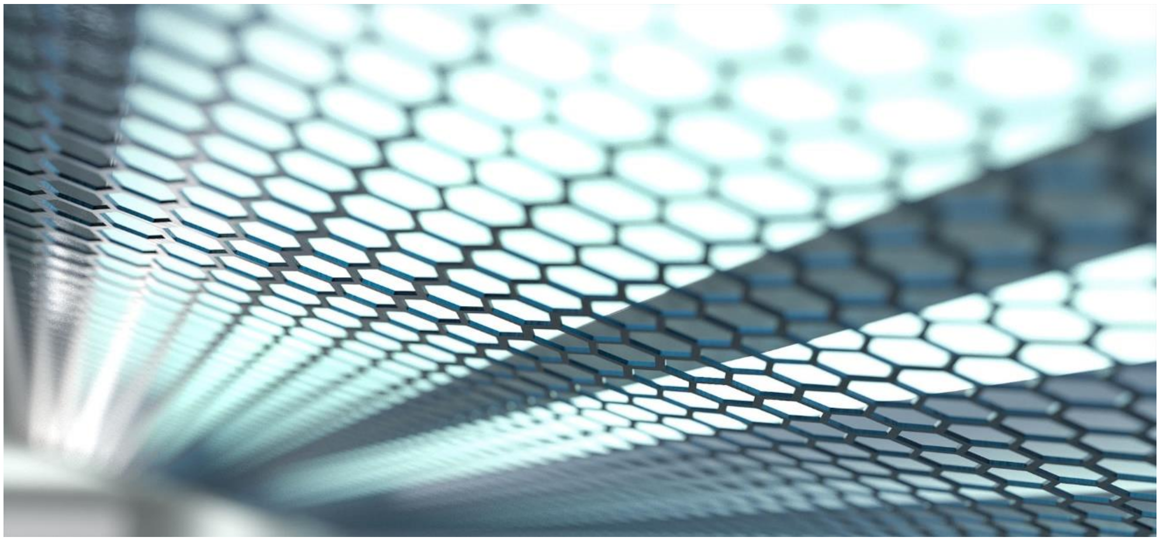
Adenovirus Ultraviolet Susceptibility

Adenovirus is one of the most UV-resistant pathogens (Kowalski 2009). Adenoviruses can employ host machinery to repair UV-induced damage, so host cell characteristics can play an important role in their UV disinfection (Battigelli 1993; Shin 2005). The Ultraviolet Disinfection Guidance Manual (USEPA 2006) recommended a LP UV dose of 186 mJ/cm^2 (1860 J/m^2) for a 4-log reduction of based on statistical analysis of published data. This is a challenging dose to achieve in water systems.

In air, however, adenovirus is considerably more susceptible to UV inactivation. Table 2 summarizes all the available studies on adenovirus inactivation by LP lamps (254 nm) ultraviolet light in air. The results indicate the average UV dose for 90% inactivation of adenovirus is about 45 J/m^2, while the D99 is 85 J/m^2 and the D99.9 is 128 J/m^2.

Table 1: Adenovirus Ultraviolet Studies in Air and Water

Virus	Media	RH %	UVGI k m^2/J	D90 J/m^2	Average D90 J/m^2	Source
Adenovirus Type 2	Air	High	0.068	34	45	Walker 2007
		Low	0.039	59		Walker 2007
		50	0.055	42		Jensen 1964
Adenovirus Type 1	Water	-	0.0028	817	468	Wasserman 1962
Adenovirus Type 1			0.0077	299		Battiggelli 1993
Adenovirus Type 1			0.0066	350		Nwachuku 2005
Adenovirus Type 2			0.0045	514		Day 1974
Adenovirus Type 2			0.0048	480		Rainbow 1973
Adenovirus Type 2			0.0036	640		Rainbow 1970
Adenovirus Type 2			0.0046	500		Bosshard 2013
Adenovirus Type 2			0.0043	533		Linden 2007
Adenovirus Type 2			0.0077	300		Shin 2005
Adenovirus Type 2			0.0058	400		Gerba 2002
Adenovirus Type 2			0.0083	276		Ballester 2004
Adenovirus Type 2			0.0138	167		Eischeid 2009
Adenovirus Type 4			0.0025	921		Nwachuku 2005
Adenovirus Type 5			0.0058	400		Durance 2005
Adenovirus Type 5			0.0043	541		Wang 2004
Adenovirus Type 5			0.0032	720		Nwachuku 2005
Adenovirus Type 6			0.0059	390		Nwachuku 2005
Adenovirus Type 6			0.0058	400		Battiggelli 1993
Adenovirus Type 15			0.0058	396		Thompson 2003
Adenovirus Type 40			0.0077	300		Meng 1996
Adenovirus Type 40			0.0042	546		Thurston-Enriquez 2003
Adenovirus Type 41			0.0098	236		Meng 1996
Adenovirus Type 41			0.0054	425		Malley 2004
Adenovirus Type 41			0.0042	555		Ko 2005
Adenovirus Type 41			0.0038	600		Durance 2005



Conclusions

The average UV dose for 90% inactivation of adenovirus in air is about 45 J/m^2. The D99 would be 85 J/m^2 and the D99.9 would be 128 J/m^2. These are achievable UV dose for ventilation air disinfection systems and forced air systems designed to intercept adenovirus should be capable of protecting occupants in indoor environments from inhalation exposure as well as reduce indoor surface contamination from settled virions, dust particles or droplet nuclei expelled by any infected individuals. Needless to say, UV systems capable of imparting such a high UV dose would likely be effective against a wide array of other human pathogens that are not so resistant to ultraviolet disinfection.

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