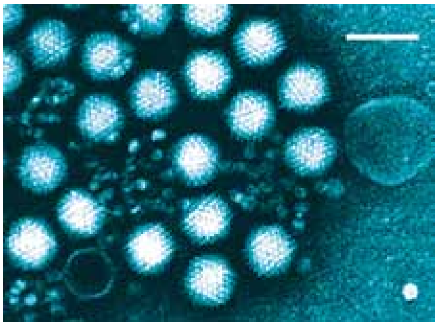
Adenovirus: Balancing Water Treatment Challenges

= 100 nm



Adenoviruses viewed by electron microscopy. Photo credit: F.P. Williams, U.S. EPA.

By Kelly A. Reynolds, MSPH, Ph. D.

Human adenoviruses are wide spread in the environment and frequently associated with disease, including respiratory infections, conjunctivitis and gastroenteritis. Although the virus is listed as a priority contaminant on the U.S. EPA Contaminant Candidate List (CCL), little is known about its presence in source or treated drinking waters. We do know that adenovirus has unique characteristics of survival helping it to persist in the environment and there is justified concern over the potential for waterborne adenovirus disease transmission.

Properties of Adenovirus

Adenoviruses are medium-sized, ranging from about 90-100 nm in diameter. They have a characteristic icosohedral (a solid with 20 plane surfaces) shape and a double-stranded DNA genome—the only double stranded human DNA virus known to be waterborne. Currently there are 51 known serotypes, most of which are associated with respiratory illnesses and cold-like symptoms. First recognized in an outbreak of acute respiratory disease among military recruits during World War II, the virus has since been identified as the cause of 5 percent of acute respiratory disease in children and 10 percent of infantile diarrhea.

Adenoviruses are primarily transmitted via direct contact between persons, or fecal-oral transmission, and sometimes via water. Although more commonly associated with recreational waters, they have been linked to two recent drinking water outbreaks of gastroenteritis[4,8]. Most (95 percent) of the adenoviruses isolated from ill patients belong to a few distinct serotypes. In decreasing order of prevalence, they are: 2, 41, 7, 3, 5, 40, 4, 31, 21, and 8. Acute respiratory disease is common with adenovirus serotypes 4 and 7 and has been identified primarily in military recruits and less frequently in civilian populations. Types 2 and 5 cause acute respiratory illness in early childhood and even infect children during the first few months of life. Type 3 causes acute pharyngocon-junctival fever, primarily in older children and adults, and has been identified in outbreaks in summer camps and swimming pools. Sporadic infections and occasional outbreaks of conjunctivitis have been linked to adenovirus serotypes 8, 19, and 37. Types 40 and 41 are most commonly associated with gastroenteritis (i.e., diarrhea) and cause infections primarily in children. The enteric adenovi-ruses are estimated to cause between 4-20 percent of gastroenteritis in young children, who may excrete 10^{11} adenovirus particles/g feces during infection.

Various serotypes of adenoviruses are hardy survivors outside their host cells and have been shown to persist for weeks on environmental surfaces. They have the ability to be transmitted by both inhalation and ingestion routes, raising the question of whether or not aerosols, such as those produced during showering, could be a significant transmission route of respiratory disease causing viruses present in water.

Water treatment: two steps forward, one step back

The use of disinfectants for the microbial treatment of public water supplies has been listed as one of the greatest public health advances of the 20th century. Currently, chlorination is the most widely used disinfectant in the United States and has been vital for minimizing the microbial waterborne disease scourges of the past (i.e., cholera, typhoid, bacterial dysentery, etc.). A major problem, however, is that chlorine can combine with contaminants naturally present in source waters (i.e., organic matter and bromine), producing harmful disinfection by-products (DBPs) that are linked with or suspected to cause a variety of adverse human health effects, from reproductive disorders to cancer. Conventional chlorine disinfection of public water supplies is not an effective barrier for human protozoan pathogens, such as *Cryptosporidium* and *Giardia*, which are major waterborne pathogens. Ultraviolet light irradiation (UV) can effectively inactivate these hard to kill protozoa, without producing harmful disinfection byproducts. However, adenoviruses pose a new challenge.

Adenovirus tend to survive longer than other enteric viruses in surface and tap waters[1]. In addition, they are the most UV-light resistant waterborne agent identified to date[2]. For example, to achieve a four-log (i.e., 99.99%) inactivation of adenovirus type 40, researchers have found that a UV dose of up to 226 mW/cm^2 is required, much greater than the dose required for poliovirus, hepatitis A virus or *Cryptosporidium*[6]. In addition, research suggests that adeno-viruses are capable of repairing the damage caused by irradiation and reverting back to an active, reproductive state. It is thought that during UV-light disinfection, only one strand of the double-stranded nucleic acid is damaged. Therefore, the other strand, presumably still intact, can serve as a template for repair by the host cell enzymes. In other words, the virus is able to genetically "convince" the cell it has invaded to recognize UV-damaged sites and fix them.

Occurrence of Waterborne Adenovirus

There are few studies evaluating the occurrence of adenoviruses in water, however, available data suggests that they are more common in sewage and sewage—contaminated surface waters than enteroviruses[7]. Although enteroviruses have served as the primary enteric virus indicator in previous studies of environmental contamination, survival, and treatment, adenoviruses occur in primary sewage at 10-fold their concentration. Recent studies have also found significant adenovirus levels in coastal waters[3].

Research conducted in South Africa involved the collection of 204 treated drinking water (with complete conventional treatment and chlorine disinfection) and 102 raw water samples at two drinking water treatment plants[7]. Over 4 percent of the treated and 12 percent of the raw waters were found contaminated with infectious adenovirus. The occurrence of adenoviruses in treated tap water from a poor quality raw water source in Korea has also been recently reported[5]. In this study, human adenoviruses were present in approximately 39 percent of the treated water samples. Because low levels of adenovi-ruses in drinking water could result in significant risks of infection and mortality in sensitive sub-populations, any detectable level of infectious adenoviruses is a public health concern.

Preventative Approaches

The majority of adenovirus infections are mild and self-limiting. In fact, most of us have been infected by the time we reach the age of 10. For some, the infection is debilitating or severe. Immunocompromised populations (i.e., cancer chemotherapy patients, AIDS patients and organ transplant patients) may experience mortalities of 50 percent or more following infection. There is no treatment for adenovirus infections, only supportive therapies for treating symptoms and potential complications. Although vaccines against types 4 and 7 have been developed and previously administered to military recruits, widespread vaccines against multiple adenovirus serotypes are not available.

Adenovirus infections are highly contagious. However, outbreaks involving recreational water exposures via swimming pools can be prevented by maintaining adequate chlorine levels while increased hand-washing and hygiene control can help reduce surface and person-to-person transmission. In addition, levels of chlorine used in conventional water treatment are effective for inactivating the virus. Through proper management of drinking water treatment methods, waterborne adenovirus infections should be minimal.

Future Concerns

A foreseeable concern is that as water utilities utilize UV light treatment for control of protozoan pathogens adenoviruses will become one of the treatment-controlling microbes. In addition, UV light disinfection may be more practical treatment for many small and medium sized drinking water utilities for compliance with the U.S. EPA proposed Groundwater Treatment Rule. Currently, scientists know little about the occurrence of adenoviruses in surface waters of the United States and even less about their presence in groundwater. Therefore, data are needed specifically on the occurrence and concentration of adenoviruses, in a variety of source waters, so that an overall strategy can be formulated to balance UV disinfection with other disinfection strategies (chlorine, chlorine dioxide, and ozone) for control of both microbes and disinfection by-products.

References

1. Enriquez, C. E., C. J. Hurst, and C. P. Gerba. 1995. Survival of the enteric adenovirus-40 and adenovirus-41 in tap, sea and waste-water. Water Research. 29:2548-2553.

2. Gerba, C. P., N. Nwachuku, and K. R. Riley. 2003. Disinfection resistance of waterborne pathogens on the United States Environmental Protection Agency's Contaminant Candidate List (CCL). Journal of Water Supply: Research and Technology 52:81-94.

3. Kukkula, M., P. Arstila, M. L. Klossner, L. Maunula, C. H. Bonsdorff, and P. Jaatine. 1997. Waterborne outbreak of viral gastroenteritis. Scandanavian Journal of Infectious Diseases. 29:415-418.

4. Lee, S. H., and S. J. Kim. 2002. Detection of infectious enteroviruses and adenoviruses in tap water in urban areas in Korea. Water Research. 36:248-256.

5. Thurston-Enriquez, J. A., C. N. Haas, J. Jacangelo, K. Riley and C. P. Gerba. 2003. Inactivation of feline calicivirus and adenovirus type 40 by UV radiation. Applied and Environmental Microbiology. 69:577-582.

6. van Heerden, J., M. M. Ehlers, W. B. Van Zyl, and W. O.K Grabow. 2003. Incidence of adenoviruses in raw and treated water. Water Research. 37:3704-3708.

7. Villena, C., R. Gabrieli, R. M. Pinto, S. Guix, D. Donia, E. Buonomo, L. Palombi, F. Cenko, S. Bino, A. Bosch, and M. Divizia. 2003. A large infantile gastroenteritis outbreak in Albania caused by multiple emerging rotavirus genotypes. Epidemiology and Infection. 131:1105-1110.

About the author

Kelly A. Reynolds is a research scientist at the Univ. of Arizona with a focus on development of rapid methods for detecting human pathogenic viruses in drinking water. She holds a master of science degree in public health from the Univ. of South Florida and doctorate in microbiology from the Univ. of Arizona. Reynolds has also been a member of the WC&P Technical Review Committee since 1997.