

# Water-Borne Transmission of Viral Infections: Implications for the Developing World

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## Abstract

Out of the nearly 700 different kinds of viruses that have been isolated from man, about 100 belong to the "enteric" virus group. They are excreted in large numbers in the feces of infected individuals. Entry of such fecal matter into the water environment leads to its pollution with enteric viruses, where these agents can survive for prolonged periods. Conventional methods of sewage and water treatment are relatively inefficient in their removal and inactivation. Virally polluted waters can, therefore, be potentially dangerous to human health when used for drinking, swimming, and cultivation of vegetables and shell fish which are consumed raw. Several water-borne outbreaks of hepatitis A, adenoviral pharyngo-conjunctival fever and acute viral gastroenteritis have been recorded. A number of other enteric viruses are also believed to be capable of water-borne spread. Even today, more than half of the people living in the developing world rely on sewage-polluted sources for their potable and recreational water needs. As a result, water-borne infections due to viruses and other infectious agents represent major problems of public health in these areas. Therefore, abatement of sewage pollution of the water environment must form an integral part of any attempt at raising the standards of health in these areas.

## Introduction

To date, nearly 700 different kinds of viruses have been isolated from human beings. These agents, which collectively produce over 50 different types of diseases syndromes, are estimated to be responsible for more than 60% of the cases of infectious disease in man. Hosts infected by a major proportion of these virus types discharge them in large numbers in their secretions and excretions. Among these are about 100 different kinds of "enteric" viruses which are excreted in the feces of infected individuals (Mahdy, 1979). Entry of such fecal matter either directly or through sewage into the water environment results in its pollution with enteric viruses. Depending on a number of factors, enteric viruses could remain infectious in fecally-polluted waters from 2 days to 6 months or more (Akin et al., 1975).

In nature, viruses present in polluted waters can enter the human body directly via the mouth, the other orifices and abrasions and breaks on the skin surface. Transmission of viruses can also occur indirectly when such waters are used for the washing of food and utensils and cultivation of shellfish and vegetables which are consumed raw.

Presently used methods of sewage as well as water treatment are relatively inefficient in the removal and inactivation of enteric viruses (Berg, 1973). Enteric viruses of human origin have in fact been isolated from samples of treated drinking water of a number of communities (Sattar, 1978). There have also been reports of enteric virus isolations from natural (Hawley et al., 1973; Denis et al., 1974) as well as treated waters used for swimming (D'Angelo et al., 1979). This review will attempt to summarize the available information on the role of potable and recreational waters in the transmission of enteric viral infections of man.

## Water-Borne Enteric Viruses

**Hepatitis A:** There is irrefutable epidemiological evidence for the capacity of hepatitis A to spread

through the consumption of sewage-polluted waters (Mosley, 1967; Goldfield, 1976). Outbreaks of this disease after exposure to sewage-polluted recreational waters have also been recorded (Bryan et al., 1974). Moreover, outbreaks of hepatitis A in man due to the consumption of raw or improperly cooked shellfish harvested from fecally-polluted waters are well-documented (Portnoy et al., 1975).

Hepatitis A virus is known to be unusually resistant to inactivation by chlorine. The 1955 hepatitis A epidemic of Delhi, India, serves as an outstanding example of this point (Dennis, 1959). This epidemic, with more than 30,000 clinical cases, occurred in spite of disinfection of the drinking water with high levels of chlorine; during this period no increase in the number of cases of enteric bacterial infections was recorded in that community.

The difficulties in the in vitro cultivation of the hepatitis A virus have discouraged attempts at its detection in water samples incriminated in the outbreaks of this disease.

**Adenoviruses:** Studies in the U.S.A. have demonstrated that the fecal shedding of adenoviruses in young children often exceeds that of enteroviruses (Cooney et al., 1972). Recently, Retter et al (1979) have shown that nearly half of the adenoviruses detected in stools by electron microscopy cannot be grown in presently available cell culture system. This simply means that the true levels of adenovirus contamination in fecally-polluted waters cannot be determined under the present circumstances.

There are no published reports incriminating potable waters in the transmission of adenoviral infections. However, a number of outbreaks of adenoviral infections spread by swimming pool waters have been recorded (D'Angelo et al., 1979).

**Enteroviruses:** Though most enteroviruses are relatively stable and are excreted in large numbers in the feces of infected individuals, direct evidence for their transmission by the water route is not yet available. Eight outbreaks of poliomyelitis thought to have been spread by potable waters have been listed by Mosley (1967). But it is believed that the epidemiological evidence for only two of these outbreaks is sufficiently strong to suggest water-borne transmission.

Polio and other types of enteroviruses have been recovered from samples of potable waters (Mahdy, 1979), but in one of these studies have their presence in the water samples been related to enteroviral infections in the community.

Outbreaks of enteroviral diseases are reported to have occurred as a result of exposure to sewage-polluted lake (Hawley et al., 1973; Denis et al., 1974) and swimming pool (Liebscher, 1970) waters. In these outbreaks the enterovirus serotypes recovered from the clinical specimens were also isolated from samples of the incriminated waters.

Although clear-cut data to demonstrate the water-borne spread of enteroviruses are presently unavailable, many investigators believe that such spread can and does occur. Goldfield (1976), for example, states that enteroviruses will eventually be shown throughout the world to be far more commonly spread by water than is hepatitis A virus.

**Viruses Causing Acute Gastroenteritis:** Acute gastroenteritis is one of the most common afflictions of man. In the developing world, this clinical condition has long been recognized as being among the major causes of morbidity and mortality (Walsh and Warren, 1979). It is estimated that in the developing parts of Asia, Africa and Latin America 5 to 18 million childhood deaths per year are due to this illness (Rhode and Northrup, 1976). It has now been established that rotaviruses are responsible for nearly 70% of the cases of this ailment throughout the world (Steinhoff, 1978; Holmes, 1979). This group of viruses has been detected in stool samples collected during certain outbreaks of diarrhea due to the consumption of sewage-polluted waters (Lycke et al., 1978; Freij et al., 1978).

A consideration of the following points further reinforces the potential of rotaviruses to spread through the water-borne route. (1) During the diarrheal phase in man, the number of rotavirus particles could be as high as 10<sup>10</sup>/gram of feces (McNulty, 1978). (2) The fecally-excreted virus particles remain infectious for several months at a temperature of 18-20°C (Woode and Bridger, 1975). (3) In a recent study (Hurst and Gerba, 1980), it has been shown that rotaviruses could retain their infectivity for several days in natural waters. (4) The conventional methods of water and wastewater treatment are

believed to be less effective in the elimination of rotaviruses when compared to that of enteroviruses (Farrah et al., 1978).

It is well established now that in addition to rotaviruses, another group of viral agents is also an important cause of gastroenteritis in man (Holmes, 1979). Significant among members of this group are the Northalk, the Hawaii and the Montgomery Country agents. Further characterization and the eventual classification of these viruses must await their in vitro cultivation. There is however, mounting evidence now for water-borne outbreaks of diarrhea by these viruses (Zweighaft et al., 1978; Ouiverkerk et al., 1978; Morens et al., 1979).

**Other Enteric Viruses:** Reoviruses are the most frequently isolated viral agents from sewage, sludge and sewage-polluted waters (Satter and Westwood, 1978). Presence of antibodies to reoviruses in 80-100% of adults in a number of communities throughout the world also shows them to be very common infectious agents of man (Leers and Rozee, 1966). However, the absence of a clear-cut relationship between reoviruses and disease production in man makes it very difficult to determine the extent of their water borne spread.

Application of electron microscopy to the direct examination of stool samples has, in recent years, led to the discovery of a variety of hitherto unknown enteric viruses (Madeley, 1979). Among these agents astro-, calici- and coro-naviruses have been implicated in outbreaks of diarrhea in man. Because of the present difficulties in their in vitro cultivation, no convincing information is as yet available on their role in outbreaks of water-borne gastroenteritis.

## Discussion

Since enteric viruses are discharged in large numbers in the feces of infected individuals, they represent the most important virus group with regard to water pollution with sewage. It must, however, be noted that a variety of non-enteric viruses, such as rubella-(Green et al., 1965), cytomegalo-(Cox and Hughes, 1974), and papovaviruses (Melnick, 1978) may also reach sewage as a result of their discharges in various secretions and excretions of infected individuals. This suggests that virtually all such viruses have the potential for transmission by the water route (Fox, 1976).

There are certain enteric viruses that can infect and grow in man as well as a variety of warm-blooded animals (Metclaf, 1976). This could be significant where untreated wastes from farms and abattoirs are discharged into the water environment. It has also been shown that migratory bird droppings can lead to influenza virus contamination of lake waters (Hinshaw et al., 1979).

Until recently emphasis was placed on viral pollution of surface waters only. It is now been shown that, at least under certain soil conditions, viruses disposed of on land could reach ground water reservoirs (Sobsey et al., 1980). Because natural purification processes are very slow in underground water reservoirs and because one would tend to use ground waters with no or minimal disinfection, even low levels of such contamination could pose a serious health hazard. Viruses can also move laterally through several feet of soil and contaminate well or spring water. This is believed to have resulted in water-borne outbreaks of viral infections (Neefe and Stokes, 1945; Mack et al., 1972).

Except for hepatitis A (Mosley, 1967; Goldfield, 1976), acute non-bacterial gastroenteritis (Goldfield, 1976; Sliman, 1978) and adenoviruses (D'Angelo et al., 1979), the evidence for the role of potable and recreational waters in the transmission of enteric virus infections is mostly indirect and circumstantial. Consideration of the following factors may explain this lack of clear-cut evidence.

1. Simple and efficient means of detecting small amounts of viruses in large volumes of water have been generally unavailable.
2. Suitable animal models to assess the potential of the waterborne route for the transmission of human enteric viruses have been very difficult to find.
3. Commonly used in vitro host systems are incapable of detecting more than 30% of the known types

of human enteric viruses (Sattar et al., 1979).

4. Sewage-polluted waters generally contain a mixture of two or more enteric virus types; higher concentrations and/or faster replication of a second virus in the same sample may mask the presence of the virus incriminated in the outbreak suspected of being water-borne.
  5. One particular type of enteric virus may manifest itself in a variety of clinical conditions and on the other hand, a given clinical condition could be produced by a number of different enteric viruses; for example, aseptic meningitis can be produced by 21 different enteroviruses, whereas one particular type of adenovirus (type 3) can cause at least four clinically distinct ailments (Rhodes and Van Rooyan, 1968).
  6. Low virus concentrations expected to be present in potable and recreational water are more likely to result in subclinical infections; passage of the virus from the subclinical case to others in his immediate surroundings makes it extremely difficult to pin down the original vehicle of infection.
  7. The damage due to relatively mild enteric viral infections may come apparent months to years later (Lake et al., 1976) so that this may in fact be the case with certain water-borne infections is exemplified by the report of Sliman (1978).
  8. Perhaps the most important factor in this regard is the lack of complete reporting of cases and outbreaks of water-borne infections (Goldfield, 1976).
  9. In view of these difficulties, it is not yet possible either to determine the risk factor or to assess the true role of potable and recreational waters in the spread of enteric virus infections. Survey conducted in certain parts of Africa suggest that improvements only in the quality of potable waters may not be enough in raising the standards of health; provision of sufficient quantities of clean water for washing and bathing as well is considered necessary to meet this aim (Walker and Walker, 1978).
- The problem of viral pollution with viruses is by no means restricted to the developing world. A number of technologically advanced countries are also plagued with it. For example, in the U.S.A. the number of water-borne cases of hepatitis A has been increasing in recent years (Mehnic, 1978). Viruses recovered from samples of treated drinking water of an urban community in the U.S.A. have been found to be unusually resistant to inactivation by chlorine (Shaffer et al., 1980). Such matters have focussed attention on the need for improvements in the methods of waste disposal and water treatment. Even today, nearly 60% of the people living in the developing world depend on sewage-polluted sources for their potable and recreational water needs. As a result, water-borne infections due to enteric viruses and other types of infectious agents results in 5-10 million deaths each each year (WHO, 1976). Therefore, any attempts to raise the standards of health in these areas must include some means of minimizing sewage pollution of the water environment.

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