ENTERIC VIRUS: RISK ASSESSMENT OF OCEAN DISPOSAL OF SEWAGE SLUDGE

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ABSTRACT

Densely populated coastal regions of the world generate large quantities of domestic sewage sludge which is often disposed into the marine environment. Present in these wastes are human pathogenic viruses which are capable of surviving for prolonged periods of time in the marine environment and transmitting disease to humans by a number of potential routes of which swimming and consumption of marine foods are the most significant.

Hepatitis A virus and Norwalk virus outbreaks associated with shellfish consumption continue to occur in the United States. Three separate epidemiological studies have also shown an association between shellfish consumption and increased risk of hepatitis A infection in consumers. An epidemiological association between non-A and non-B hepatitis has also been demonstrated.

A review of the risks of infection, clinical illness and mortality associated with enteroviruses suggests that the presence of these viruses in shellfish and bathing waters presents a significant risk to the consumer.

KEYWORDS

Sludge, ocean disposal, enteric viruses, enterovirus, hepatitis A, shellfish, swimming, risk assessment.

INTRODUCTION

Densely populated coastal regions of the United States generate large quantities of domestic sewage and sludge. These wastes are often disposed of directly into the marine environment by coastal outfalls or by dumping from barges. According to one estimate, 8 billion gallons of municipal sewage were discharged each day into the coastal waters of the United States, only half of it receiving secondary treatment (Clark, 1977). In this case sewage sludge and/or industrial wastes are barged several miles off-shore to be discharged at a specific dump site in open ocean waters. In the United States such sites include the Philadelphia dumpsite, the New York Bight site, the Puerto Rico trench dumpsite and the 106-mile ocean waste disposal site (Goyal, 1984).

Present in these wastes are human pathogenic viruses which cause a wide variety of illnesses in man including hepatitis, gastroenteritis, meningitis, fever, rash conjunctivitis, etc. Consumption of raw, steamed, or partially cooked shellfish has been recognized for over 30 years as a source of infectious hepatitis and more recently viral
gastroenteritis (Richards, 1985). Enteric viruses may also be transmitted by swimming and potentially by other aquatic recreational activities (Cabelli, 1983).

Each sludge disposal option a community may have is associated with a certain health or environmental risk. This study attempts to evaluate the risks from pathogenic human viruses associated with the ocean disposal of sewage sludge.

SLUDGE CHARACTERISTICS AND DISPOSAL METHODS

Sewage sludge is a complex mixture of solids of biological and mineral origin that are removed from wastewater in sewage treatment plants. Sludge is a by-product of physical (primary treatment), biological (activated sludge, trickling filters) and physiochemical (chemical precipitation with lime, ferric chloride or alum) treatment of wastewater. Many of the pathogenic microorganisms which are present in raw wastewaters will find their way into sewage sludges. Treatment of these sludges by anaerobic digestion and/or dewatering will reduce the number of pathogens, but significant numbers may remain (Goddard et al., 1982). The type of treatment will determine the concentration of pathogens and the relative risk of disposal.

Stabilization of sludges may be accomplished by either aerobic or anaerobic digestion, lime addition, heat, wet oxidation or incineration.

Sludges may be dewatered by a number of processes including drying beds, vacuum filtration, pressure filtration, centrifugation and heat drying. Usually chemicals such as alum, lime, ferric chloride or synthetic polyelectrolytes are added to improve the dewatering characteristics of the sludge.

The disposal of sewage and sludge in the marine environment is accomplished by construction of offshore sewage outfalls or by barging the sludge several miles offshore and then discharging it at a designated dump site on or at the edge of the continental shelf.

Submarine offshore sewage outfalls are sometimes used to convey treated effluent out to sea for disposal. It is assumed that discharging sewage by this method results in reduced pollution of adjacent beaches. However, shoreward eddies, wind and wave action may cause waste plumes to intersect bathing waters along adjacent shorelines. Several major sludge dump sites in open ocean waters have been used in the United States in recent years. These include the Philadelphia sewage sludge dump site, the New York Bight, and the 106-mile deep ocean waste disposal site. The New York Bight dump site, also known as the 12-mile site, is a coastal ocean area at the apex of New Jersey and Long Island and is situated roughly 12 miles equal distance from the shores of New York and New Jersey at the entrance of the Hudson Canyon. This site has been used for sludge disposal since 1924. The Philadelphia dump site is a 172-km² area located approximately 70 km east of Ocean City, MD. The site lies over the continental shelf in waters 40-60m deep. Sewage sludge from the cities of Philadelphia, PA and Camden, NJ was dumped at this site between 1973-1980. The 106-mile dump site is located 106 miles (196 km) southeast of Ambrose Light Tower and 167 km due east of Cape Henlopen. It has only recently been used for sludge disposal. Human enteric viruses have been detected in the seawater, sediments and crabs at both the New York Bight site and the Philadelphia dump site (Goyal, 1984).

EXPOSURE PATHWAYS

The fate of microbial enteric pathogens may take many potential routes in the marine environment. Field studies at both the New York Bight and Philadelphia dump site have shown that fecal indicator bacteria and viral pathogens occur in the surface waters and accumulate in the sediments. These organisms appear capable of existing for years in the sediment material (Goyal, 1984). Crabs in the area of the sludge disposal site have been shown to contain human enteroviruses. The crabs may become contaminated by several routes including intake of sediment material during feeding and ingestion of contaminated fish and shellfish. Shellfish, being filter feeders, tend to concentrate bacteria and viruses, and concentrations of these microorganisms in shellfish can be expected to be many times higher than the surrounding water. Consumption of viral contaminated shellfish is a continuing cause of disease outbreaks in the United States (Richards, 1985). Fish may become contaminated by the same mechanisms as crabs.
Enteric virus

Once associated with a marine organism inactivation of human enteric pathogens will probably be reduced. It is possible that pathogens may be passed through several species in the marine food chain. For example, shellfish may accumulate viruses from the marine water later to excrete them into their feces (Metcalf, 1976), which is then consumed by polychaete worms. The polychaete worms are consumed by crabs who then may excrete the pathogens into the sediment where sediment resuspension causes them to again be taken up by shellfish. The dumpsite is often closed to shellfish harvesting so that this problem is alleviated. Animals such as crabs, however, are not sedentary and may move and be caught in "clean" areas. If they are not cooked properly before consumption, they may present a risk (Hejkal, 1982; Siegel et al., 1976).

Contact with pathogens may also result from bathing or diving in polluted marine waters. It has been established that even swimming in only marginally polluted waters can result in observable increases in gastroenteritis among bathers. (Cabelli, 1983). Divers are also at increased risk of ear infections when working in sewage contaminated waters (Joseph et al., 1979). Offshore dumpsites are not used for swimming. However, any activity which acts to resuspend sediment will aid in its transport away from a disposal site. Currents, wind, storms, divers and dredging activity can result in sediment resuspension.

Aerosols may be expected to be generated during the disposal of the sludge and by wave action or dredging activities. Baylor and Baylor (1980) found that when a bacterial virus was added to ocean surf, it was readily aerosolized and detected in the air along the beach. Bacteria and viruses are concentrated from the water during aerosol formation and can occur in concentrations 50-1000 times greater in the overlaying air than in the water (Blanchard and Suzdek, 1970).

Data are not available on the generation and transport of aerosols from the dumpsite, which makes it difficult to draw any conclusions about risks associated with aerosols. It is prudent, however, to remark that marine microorganisms have been known to be transported as far as 100 miles from the ocean by winds (Baylor et al., 1977; Gruft et al., 1975).

**MARINE FOODS RISK ASSESSMENT**

Perhaps the greatest risks associated with the disposal of domestic sludges in the open occur with the entrance of these organisms into seafood meant for human consumption.

Although there are over 100 known enteric viruses, only a few have been shown epidemiologically to be transmitted by shellfish. These viruses are listed in Table 1. Lack of methods for virus detection and the difficulty of recognizing viral disease outbreaks have probably precluded the list from being longer. It was not until the early 1960's that outbreaks of shellfish-associated infectious hepatitis were documented in the United States. Since then over 1,000 cases of shellfish associated with hepatitis A virus have been reported (Richards, 1985). Outbreaks are rather dramatic but still not easily detectable. More significant are the sporadic cases which are not evident as an outbreak.

<table>
<thead>
<tr>
<th>Table 1. Enteric Viruses Documented Epidemiologically as Causes of Shellfish Associated Illness</th>
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<tr>
<td>Astrovirus</td>
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<tr>
<td>Hepatitis A</td>
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<tr>
<td>Non-A Non-B Hepatitis</td>
</tr>
<tr>
<td>Norwalk</td>
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<tr>
<td>Snow Mountain Agent</td>
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<td>Small Round Viruses</td>
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Several epidemiological studies have suggested that shellfish may play a significant role in the transmission of hepatitis A virus. In a recent case controlled study, it was reported that 25% of the hepatitis A cases in south east England could be attributed to the consumption of shellfish (O'Mahany et al, 1983). Stille et al (1972) in Germany reported that consumption of contaminated mollusks accounted for an estimated 19% of the infectious hepatitis in Frankfurt, Germany. In the United States, Koff et al (1967) conducted a prospective study to determine the modes of transmission of nonepidemic infectious hepatitis cases among 10 Boston hospitals. Ingestion of raw shellfish was found to be
significantly more frequent (34/185) in infectious hepatitis patients than in controls (10/185). Ingestion of steamed clams (13/104) was more common in patients than matched controls; only 3 of the 13 patients had been exposed to jaundiced persons. When considered together, ingestion of steamed clams or raw shellfish was as frequent a potential exposure to hepatitis as was contact with jaundiced persons.

Three recent reports have implicated shellfish as a source of non-A non-B hepatitis (Alter et al., 1982). In a study of patients in five Baltimore, Maryland, hospitals, Alter et al. (1982) found that raw shellfish ingestion was associated with 12.5% of the cases of non-A, non-B hepatitis. This was the third most common risk factor after parental drug use and history of blood transfusions. It is possible that different non-A non-B hepatitis viruses were associated with the shellfish than with parental drug use and blood transfusion.

Numerous studies have been conducted on the survival of viruses in marine waters. Enteric viruses have been reported to survive from 2-130 days in seawater in laboratory studies and generally survive longer in such environments than coliform bacteria (Melnick and Gerba, 1980). However, Goyal et al. (1984) was able to isolate enteroviruses from sediment and blue crabs at the Philadelphia dump site 18 months after sludge disposal had stopped. A number of variables have been found to affect virus survival. These include temperature, salinity, microbial antagonism, solar radiation, and association of viruses with solids (Kapuscinski and Mitchell, 1981). Of the many factors which can influence virus survival, temperature is the most important. At temperatures below 10°C enteric viruses could be expected to survive for several months (Gerba and Goyal, 1986). Marine sediments also act to protect viruses against inactivation, perhaps by reducing the rate of thermoinactivation (Liew and Gerba, 1980). Generally when sediment is present inactivation rates of viruses in seawater-moistened sand tended to be 4.5 fold slower than in seawater alone (Gerba and Goyal, 1986). This probably explains why Goyal et al. (1984) was able to detect enteric viruses in marine sediments at the Philadelphia sludge dumpsite 18 months after disposal had stopped.

INFECTIVE DOSE AND RISK OF DISEASE

From the previous review it is evident that enteric viruses are present in commercially harvested shellfish and that this is leading to continued occurrence of viral-associated illness. The exact risk of illness of enteric viruses in water and marine food from exposure is difficult to quantitate. Since currently used bacteriological indicators do not reflect the occurrence of enteric viruses, approaches are needed to assess the risk of illness when ingestion occurs.

Important in any risk assessment is the level or concentration of contaminant which is necessary to cause a health effect. Ideally, maximum contaminant levels for potentially harmful substances would be established on firm epidemiological evidence where cause and effect can be clearly quantitated to determine a minimum- or no-risk level. However, while epidemiology is a valuable tool for detecting patterns of risk and establishing statistically significant associations with risk agents, it cannot easily quantitatively demonstrate cause and effect. Estimating data on minimum infectious dose (MID) for humans is generally not possible because of the extreme cost, unethical nature of human
Enteric virus experimentation, and uncertainty in extrapolating dose-response curves to low exposure levels.

Ward and Akin (1984) have recently reviewed the literature on MID of human viruses in a limited number of healthy individuals. Still, the results indicate that relatively low numbers of enteroviruses, perhaps 1 or 2 tissue culture plaque forming units (PFU), are capable of causing infection. It should be realized, however, that infection does not necessarily mean disease.

The most extensive studies to date on MID by enteric viruses have been conducted by Schiff et al. (1984) and Ward and Akin (1984). Over 100 healthy adult volunteers were fed various doses of echovirus 12, a very mild pathogen, in drinking water. By use of probit analysis an estimated average MID of 17 PFU was obtained. More recent research in animal and human subjects indicates that oral ingestion of one plaque forming unit of rotavirus will result in infection (Ward et al., 1986; Graham et al., 1987).

Unlike risks associated with toxic chemicals in water, individuals who do not actually consume or come into contact with the contaminated water or sludge are also at risk. This is because microorganisms may also be spread by person-to-person contact or subsequent contamination of other materials which noninfected individuals may come into contact. This secondary and tertiary spread of microorganisms has been well documented during waterborne outbreaks caused by the Norwalk virus (Gerba et al., 1985). In the case of Norwalk outbreaks, the secondary attack rate is ~30% (Gerba and Goyali, 1986).

### ESTIMATED MORBIDITY AND MORTALITY FOR ENTERIC VIRUSES

Not everyone who may become infected with enteric viruses will become clinically ill. Asymptomatic infections are particularly common among some of the enteroviruses. The development of clinical illness depends on numerous factors including the immune status of the host, age of the host, virulence of the microorganisms, type, strain of microorganism, and route of infection. For hepatitis A virus, the percentage of individuals with clinically observed illness is low for children (usually <5%) but increases greatly with age. In contrast the frequency of clinical symptoms for rotavirus is greatest in childhood (Gerba et al., 1985) and lowest in adulthood. The observed frequencies of symptomatic infections for various enteroviruses range from 0.1 to greater than 50%. While the frequency of clinical hepatitis A virus in adults is estimated at 75%, during waterborne outbreaks it has been observed as high as 97% (Lednar et al., 1985).

Mortality rates are also affected by many of the same factors which determine the likelihood of the development of clinical illness. The risk of mortality for hepatitis A virus in the United States is 0.6% (CDC, 1985). Mortality from other enterovirus infections has been reported to range from <0.1-1.8% (Assaad and Borecka, 1977).

### SUMMARY AND CONCLUSIONS

The purpose of this document was to identify human pathogens associated with sewage sludge and the risks posed by them following the ocean dumping of sludge. Background information on pathogens of concern and their persistence in marine environment has been presented. Attempts have also been made to identify different routes by which pathogens can reach man and to estimate risks associated with each of the potential routes.

Because of a limited number of studies on pollution of marine environment by sludge disposal, it is difficult to assess these risks. We know that the pathogens can persist in sediments for an extended period of time and that animals (i.e., rock crabs) dwelling at the dumpsite can pick up these organisms and move away from the site. We also know that sludge impacted sediments can drift long distances from point of discharge. Whether these sediments (and their associated pathogens) can reach coastal environment does not seem likely under normal conditions but in the event of storms and quakes, it is a distinct possibility. It is logical to assume that it is less likely to happen when sludge is disposed at 106-mile site than at the New York Bight or Philadelphia dump sites, because of the distances involved.

Predictions on viral and bacterial decay following ocean disposal of sludge will require information on the vertical and horizontal movement of discharged sludge as well as on the survival of pathogen attached to sludge particles. The latter information is not currently available.
available. Studies on how far aerosols can travel and how long pathogens can survive in them are also incomplete. Obviously, large numbers of health events will be related to consumption of seafood (from in and around the dump site) than to swimming because of the bioconcentration of pathogens by filter feeders.

REFERENCES


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