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Project Summary

Qualitative Pathogen Risk Assessment for Ocean Disposal of Municipal Sludge

This document focuses on microbial contaminants of municipal wastewater sludges that have been actually or potentially implicated in producing human illness; it summarizes available data on the occurrence, transport and fate of these pathogens in the marine environment; and describes the possible hazards to human health associated with the disposal of sludges in open ocean waters. Following the presentation of background information, a discussion of risks associated with ocean disposal of sludge are presented. The scope of the risk assessment is restricted, therefore, to pathogens present in municipal sludge discharged at the open ocean dump sites.

Because of a limited number of studies on the pollution of marine environments by sludge disposal, it is difficult to assess these risks. It is known that pathogens can persist in sediments for an extended period of time and that animals (for example, rock crabs) dwelling at a dump site can pick up these organisms and move away from the site. It is also known that sludge-impacted sediments can drift long distances from point of discharge. Whether these sediments (and their associated pathogens) can reach coastal environments 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 this pollution is less likely to happen when a sludge is disposed at the 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 pathogens attached to sludge particles. The latter information is not currently available. Studies on how far aerosols can travel and how long pathogens can survive in them are also incomplete. Obviously, consumption of seafood (from in and around a dump site) is riskier to health than swimming because of the bioconcentration of pathogens by filter feeders.

This Project Summary was developed by EPA's Environmental Criteria and Assessment Office, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Ocean disposal of domestic sewage and sludge has been carried out off the coast of the United States since the New York Bight site opened in 1924. Discharge of waste at sites such as the

New York Bight (to be closed in 1988), the Philadelphia dump site (closed in 1980), the Puerto Rico Trench dump site (closed) and the 106-mile deep water ocean waste disposal site in the mid-Atlantic Bight (which opened in March 1986 on a five-year interim basis) has generally been accomplished from barges. The amount of sludge dumped into the ocean by U.S. municipalities and industries in the 1970s was estimated to be 5×10^6 wet metric tons/year.

Human exposure to pathogenic microorganisms from ocean-disposed sludge may occur through primary contact recreation such as bathing, scuba and skin diving, water skiing, and during occupational activities such as commercial and military diving operations. In addition, ingestion of raw or partially cooked seafood that has become contaminated may be harmful. Bivalve mollusks such as oysters and clams are of particular concern because they feed by filtering particulate matter, including microbes contained in large volumes of seawater. Inhalation of contaminated dust or aerosol droplets containing pathogens from sewage is also a potential exposure route.

Sludge Characteristics and Disposal Methods

Ocean disposal of sludge is accomplished by construction of offshore sewage outfalls or by barging the waste several miles offshore and discharging it at a designated dump site. Because offshore outfalls have been shown to release high concentrations of bacteria and viruses into marine waters, the principal method of ocean disposal is to dump sludge into a barge, tow the barge to a disposal site, open disk valves fixed in the bottom of specially constructed holding tanks in the hull of the barge,and allow the sludge to drift away. Sludge may be dumped from a moving barge (line dump, which results in the greatest dispersal) or from a stationary barge (spot dump).

The New York Bight dump site began receiving municipal sludge in 1924 and will cease operations in 1988. The site is a coastal ocean area at the apex of New Jersey and Long Island situated roughly 12 miles (19.2 km) equidistant from the shores of New York and new Jersey at the entrance to the Hudson Canyon. The sludge dumping area occupies 100 km^2 at latitude 40°25'04"N and longitude 73°44'53"W. Depth at the dump site is ~30 m, and bottom temperature ranges from 9.8-12.3°C in the summer. During 1965-1970, the average annual input of sludge to the New York Bight was 3.2×10^9 kg.

Fecal coliforms have been isolated from New York Bight bottom sediments in concentrations as high as 2.3×10^4/100 mℓ, and coliform bacteria have also been found in crabs, lobsters and scallops that inhabit the area. *Acanthamoeba* protozoa and human enteroviruses such as coxsackie B3 and B5 ($\leq$108/kg of sediment) and echo 1 and 7 ($\leq$182/kg) have been identified in surface water, sediment and crabs collected from this dump site. However, no evidence exists that sewage sludge disposal at the New York Bight dump site increases the risk of swimming-associated disease at any New Jersey, New York City or Long Island beaches. Moreover, *Clostridium perfringens* spore densities in the water column or bottom sediments indicate that dumped sludge does not reach the shore in significant quantities anywhere along the Bight.

The Philadelphia sewage sludge dump site is a 172-km^2 area located ~70 km east of Ocean City, MD, at roughly 23°23'N and 74°15'W. The site, which lies over the continental shelf in waters 40-60 m deep, received sludge from Philadelphia, PA, and Camden, NJ, from 1973 until its closing in 1980. Between 1973 and 1977, 2.8×10^9 kg of sludge was deposited there.

Changes in the benthic environment in the vicinity of the Philadelphia site during and after its operation have included accumulation of metals and other toxics in organisms and sediment, alterations in community structure, changes in abundance of various species, increased rates of mortality of the ocean quahog (*Artica islandica*) and the appearance of sludge beds, sewage bacteria (total coliforms, fecal coliforms and fecal streptococci), pathogenic protozoa (*Acanthamoeba*), human enteroviruses (coxsackie B3 and B5, echo 1 and 9 and polio 2) and diseases in crabs.

The 106-mile deep water site off the New Jersey coast was used primarily for disposal of $>5 \times 10^6$ metric tons of chemical wastes from 1961-1978. Only ~4×10^5 metric tons of sludge were dumped at the 106-mile site before 1978, but in 1984 EPA designated the area as a permissible sewage sludge disposal site on a five-year interim basis. Furthermore, as of March 1986 permittees using nearshore sites may dispose of wastes at the 106-mile site. It is expected that ~7×10^6 metric tons of New York/New Jersey sewage currently being dumped at the 12-mile site will be discharged at the 106-mi site.

The Puerto Rico Trench dump si was used primarily for pharmaceutic wastes and is now closed for dumping.

Pathogens of Concern

Processed sewage wastes ma contain residual pathogens, such a viruses, bacteria, cysts of protozoa ar ova of helminths. However, mo outbreaks of sewage-related diseas have been attributed to the use of ra sewage, raw sludge or night soil on foo crops consumed raw, and t contamination of drinking water fro septic tanks or by consumption of ra shellfish from sewage-polluted water The principal pathogens found in sewag can be divided into four groups: bacteri protozoa, helminths and viruses. Sewag treatment practices reduce the number the four groups of pathogens, but there evidence to indicate that effluents ar sludges contain detectable amounts. Th amounts and variety of pathogen present in sewage vary from communi to community and are dependent upo urbanization, season, population densit ratio of children to adults and the sanita habits of the community.

Exposure Pathways

Potential pathways of enteric pathoge transport in the marine environment a illustrated in Figure 1.

Field studies at the New York Big and Philadelphia dump sites have shov that fecal indicator bacteria and vir pathogens occur in surface waters an accumulate in sediments. Crabs in th vicinity of these sludge disposal site have been shown to contain huma enteroviruses. Such contamination ma occur through intake of sediment mater during feeding and by ingestion infected fish and shellfish. Shellfish a filter feeders and tend to accumula bacteria and viruses at much high concentrations than the surroundi water. It is possible that pathogens m be passed through several species in t marine food chain.

Contact with pathogens may al result from bathing or diving in pollut marine waters. Although ocean dun sites are located offshore, currents, wir storms and dredging activity can result resuspension and transport contaminated sediments to nearsho locations that may pose a potential risk human health.

Aerosols generated during disposal sludge and by wave action or dredgi

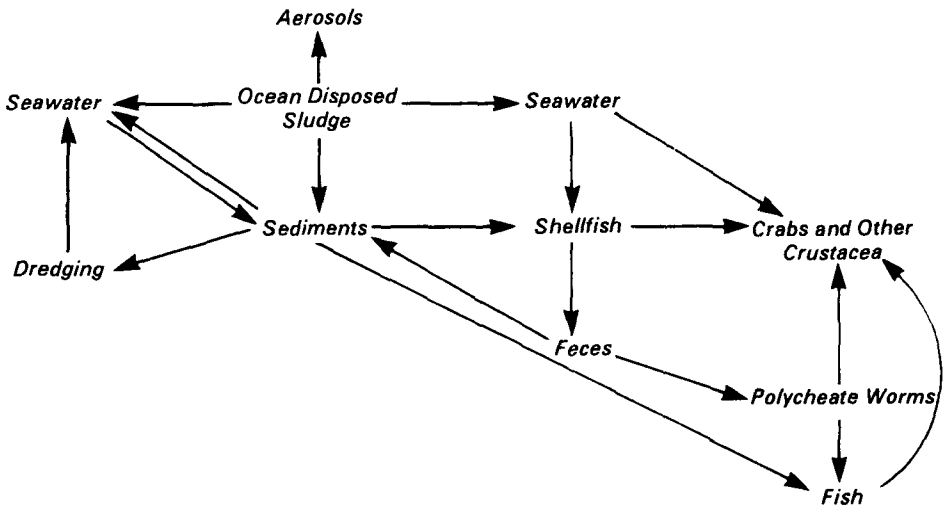

Figure 1. Potential pathways of enteric pathogen transport in the marine environment.

activity may transport bacteria and viruses as far as 160 km from the ocean by winds.

Persistence of Pathogens in the Marine Environment

The survival of fecal indicator bacteria and viruses in marine waters has received a great deal of attention. Numerous studies have been conducted on the factors controlling the survival of specific bacteria pathogens, protozoa and helminths.

Sunlight and temperature appear to be the dominant factors controlling survival of coliform bacteria in marine waters,but salinity also plays a role. Temperature is critical to viral survival, and sunlight may be important but its influence has not been studied extensively. Persistence of these pathogens in sediments and in mollusks appears to be prolonged; however, no previous studies have been conducted on survival of sludge-associated microorganisms in the marine environment. Field studies at the Philadelphia dump site suggest that sludge accumulated in sediments may greatly prolong or cause the growth of fecal indicator bacteria.

Bacterial and viral survival in water follows an exponential curve, so that the probability of a bacterium dying in a given time interval is independent of its age. Time for 90% inactivation of coliform bacteria is considerably faster for seawater (0.6-8 hours) than for freshwater (20-115 hours). Inactivation time decreases sharply with increasing temperature. In warm climates with sewage temperatures of 25-30°C, >99% reduction in indicator bacteria concentration may be expected in 10-15 days.

Enteric viruses have been reported to survive from 2-130 days in seawater in laboratory studies. Time for 90% inactivation has been estimated to be between 15 and 70 hours.

Survival of amoeba cysts in water is primarily dependent upon temperature. At 25QC, *Entamoeba histolytica* may survive for 7-20 days; survival time at 5°C may be >1 month. Sewage treatment may remove 52-93% of *Giardia* cysts.

Laboratory experiments have determined that 97% of *Ascaris* eggs are killed after two days in seawater. *Ascaris* eggs are considerably hardier than *Trichuris*, hookworm or *Entrobius* eggs, but somewhat less resistant than *Taenia* eggs. Hookworm eggs can survive in sludge at 27°C for ≤43 days, but in seawater their survival is <5 hours compared to >30 hours for *Ascaris* eggs. Helminth eggs tend to settle in seawater and accumulate in bottom sediments.

In estuary water >80% of fecal indicator bacteria are directly associated with suspended sediments, and this association appears to prolong their survival in the aquatic environment. Several recent field studies indicate that, on a volume basis, greater numbers of coliforms and bacterial pathogens occur in bottom sediments than in overlying water. Coliform bacteria have been detected in areas of sludge disposal at both the Philadelphia and New York Bight dump sites; at the Philadelphia location, the microbes survived ≤4 years after the last sludge was dumped. Fecal indicator bacteria with multiple drug resistance were found 30 months after cessation of sludge dumping.

Field studies have documented the occurrence of enteroviruses and rotaviruses in marine sediments, and laboratory studies have demonstrated that virus adsorption to sediments prolongs survival time in marine waters. Enteroviruses were isolated from sediments taken from the Philadelphia sewage sludge dump site 17 months after dumping stopped, but tests for viruses were negative 24 and 36 months after the site's closure.

Infective Dose for Microorganisms

Estimation of minimum infectious doses (MIDs) for various pathogens in polluted marine water, food and sediments is difficult because of uncertainties in the immune status of host, assay technique, sensitivity of host, virulence of pathogen, use of upper 95% confidence limit, route of exposure, choice of dose-response model, synergism/antagonism, dietary considerations and distribution of subjects among doses and number used. In addition, it should be realized that infection does not necessarily mean disease.

In many studies, small numbers of viruses (as few as 1 or 2 tissue culture plaque-forming units), primarily vaccine strains, have produced infection in human subjects. The infective dose of protozoan cysts such as *Giardia lamblia* and *Entamoeba* by the oral route appears to be as low as between 1 and 10 cysts. Essentially one helminth egg can be considered to be infectious, although symptoms may be dose related.

MIDs for bacteria are generally higher than those for viruses and parasites. The number of ingested bacteria required to cause illness appears to range from 10^2-10^8, although recent studies suggest that the infective dose for *Salmonella* may be <10 organisms. Virulence of the particular type and strain of microorganism and host factors may play roles in determining the actual number of microbes required to cause infection.

Qualitative Risk Assessment

Because of a limited number of studies on the pollution of marine environments by sludge disposal, it is difficult to assess the risks. It is known that pathogens can persist in sediments for an extended period of time and that animals (for example, rock crabs) dwelling at a dump site can pick up these organisms and move away from the site. It is also known that sludge-impacted sediments can drift long distances from the point of discharge. Whether these sediments and their associated pathogens can reach coastal environments 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 this pollution is less likely to happen when sludge is disposed at the 106-mile site than at the New York Bight or Philadelphia dump sites because of the distances involved.

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In summary, with what little information is available, it is only possible to speculate on the occurrence of huma health risks from pathogens in municipa sludge disposed in the ocean. More research is needed in order to develop a definitive risk assessment methodology.

This Project Summary was prepared by staff of the Environmental Criteria and Assessment Office, Cincinnati, OH 45268.
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The Complete report entitled "Qualitative Pathogen Risk Assessment for Ocean Disposal of Municipal Sludge," (Order No. PB 89-126 593/AS; Cost: $21.95, subject to change) will be available only from:
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