Public Health Aspects of OSDS

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Residential On-site Sewage Disposal Program

Indiana State Department of Health

Introduction

The term 'OSDS' is used throughout this document. 'OSDS' means 'on-site sewage disposal system' or its plural 'on-site sewage disposal systems' depending on the context.

There are two basic components in an OSDS:

1. Septic tank
2. Soil absorption field

The septic tank lets gravity separate solids that can settle from liquid wastes, retaining the solids (sludge) and floatable materials (scum), so bacteria can decompose them. These separation and decomposition processes are called primary treatment. However, the bacteria cannot completely breakdown all the sludge and scum. Therefore, septic tanks need to be pumped periodically by a professional. The liquid wastewater cannot be disposed indiscriminately, because of the contaminants that it may carry. The liquid wastewater must be discharged to a soil absorption field where it undergoes the final treatment through the processes of physical filtration, chemical reactions, and biological transformations.

According to the 1990 census, there are more than 25 million OSDS in the United States. This is an increase of more than three million since 1980. Currently, about 25 percent of the population depend on OSDS. It is expected that this percentage may increase in the future as more and more people move away from the cities to more rural areas[27].

OSDS that have been properly designed, constructed, operated and maintained are efficient and economical alternatives to public sewage disposal systems[3]. However, U.S. Environmental Protection Agency (EPA) studies indicate that about one-third of all OSDS operate improperly. As a result of this, OSDS are the primary source of groundwater contamination in many parts of the country[2]. Approximately half of the drinking water used in the United States is derived from groundwater and nearly half of the waterborne outbreaks are attributed to contaminated groundwater. Contamination of groundwater from OSDS failure has been implicated up to forty percent of groundwater attributed outbreaks[10].

Also, dwellings built near beaches may be equipped with underground OSDS, which if not sited, built, operated and maintained properly, can leach wastewater into beach recreational waters. Bathing beaches can be contaminated with fecal matter from malfunctioning or overloaded OSDS. Runoff can also carry microorganisms from failing OSDS far from the shore into streams, which empty into bays near beaches[21].

Contaminants

The contaminants in domestic wastewater can be divided into two categories:

1. Pathogens:
   - Viruses
   - Bacteria
   - Protozoa
   - Helminths
2. Chemicals:
   - Nitrates
   - Toxic organic compounds

The types of viruses in inadequately treated wastewater can cause a wide variety of diseases ranging from gastroenteritis to infectious hepatitis. Bacteria in inadequately treated wastewater can cause diseases ranging from gastroenteritis to typhoid fever. Protozoa are unicellular organisms and exist as environmentally stable cyst form. They cause gastroenteritis and dysentery[10]. Helminths are intestinal worms and their eggs can survive longer in an OSDS or in the environment. The major health problems they cause are gastroenteritis and chronic anemia. Certain toxic algae that grow on surface water sources due to high nitrate discharges can cause a wide range of diseases from gastroenteritis to neurotoxic poisoning[23]. The important representatives of the four pathogens are included in Table 1(see page 9).

Some general symptoms of waterborne diseases include headache, fever, abdominal discomfort, diarrhea (sometimes with blood), nausea and vomiting. In addition to these symptoms, exposure to sewage contaminated recreational waters can cause skin rashes, ear, nose, throat and eye irritations and respiratory discomforts[23]. Depending on the organism involved, symptoms can begin hours to several days after ingestion or exposure.

Case Studies for Waterborne Outbreaks due to Wastewater Contamination

Hepatitis A

An outbreak of 98 cases of hepatitis A was reported in Polk County, Arkansas, in 1971. The outbreak was traced to commercial pellet ice made from well water at a general store. Both the ice and the well water showed heavy coliform contamination. Dye studies revealed that the sedimentary rock strata in the area permitted lateral drainage of septic tank effluent from a nearby home occupied by residents who had infectious hepatitis six weeks previously[1].

Norwalk Gastroenteritis

An outbreak of Norwalk gastroenteritis occurred at a camp in Colorado in 1976, resulting in 418 persons with gastroenteritis at the camp or within a week of leaving it. The camp was supplied with water by a natural spring at the base of a small hill. At the top of the hill was a private cabin with a septic tank approximately 50 feet above the spring. Fluorescein dye flushed into the cabin wastewater system rapidly appeared in the spring and in the camp tap water. The septic tank, set in fractured shale and decomposed granite, was unearthed and a hole in the leaching pipe several feet away from the tank was found. Norwalk viruses were detected in diarrhoeal stool specimens[1].

An outbreak of diarrhea occurred among 331 participants in an outing held at a South Dakota campground on August 30 and 31, 1986. Water from a well at the campground had been used to fill water coolers and to prepare a powdered soft drink. Fluorescein dye injected into a 5,000 gallon septic tank situated uphill from the well confirmed that the well was contaminated with sewage. A biotin-avidin immunoassay performed at the Centers for Disease Control and Prevention (CDC) yielded a fourfold rise in antibody titer to Norwalk virus in 7 of the 11 human serum specimens[20].

Viral Gastroenteritis

In 1995, an outbreak by a small round structured virus was documented. The outbreak occurred in September at a high school in Wisconsin and affected 148 persons. The school received its drinking water from a community water supply. Contamination of the potable water system likely occurred from backsiphonage of water through hoses submerged in a flooded football field. However, the source of the virus on the field was not determined[11].

An outbreak in 1995 at the restaurant of a resort in Wisconsin might have been caused by a rotavirus. The state laboratory reported identifying rotavirus in two of six stool specimens with an enzyme immunoassay. However, no testing was done for Norwalk-like viruses, which have been more commonly associated with waterborne disease outbreaks than the rotaviruses[11].

St. Louis Encephalitis

St. Louis encephalitis is an epidemic disease caused by a virus. It was first recognized following an outbreak in St. Louis in 1933. Wild birds are the normal hosts of this virus. The virus is transmitted from bird to bird by three species of *Culex* mosquitoes that commonly occur in Indiana. *Culex pipiens* which is also known as the northern house mosquito, has an uncanny ability to finds its way into structures at night and take a blood meal from the occupants. As such, humans become involved as accidental intruders into the cycle[25].

Two large outbreaks of St. Louis Encephalitis had occurred in the southwestern part of Indiana in 1955 and 1964. In 1975 the entire Midwest experienced a large epidemic in which 323 laboratory-confirmed cases were reported from Indiana with 17 deaths. A smaller outbreak was reported from Vincennes, Indiana in 1980[25].

Following the epidemic of 1975, survey work in those counties which were hit the hardest resulted in the identification of environmental conditions which contributed to large numbers of vector mosquitoes in close proximity to patients. In almost all cases sewage contaminated surface water was found to provide extensive breeding areas for all three vector species of *Culex.* In addition, the presence of special situations such as improperly maintained lagoons, catch basins, and containers such as used tires were found in abundance[25].

Typhoid

In spring 1972, five cases of typhoid occurred in a residential area near Yakima, Washington that was served by individual driven well points and OSDS. Upon investigation, a typhoid carrier was identified in the area. Dye flushed from the sewage system of his home was traced within 36 hours to numerous wells in the area including the ill family's well, which was 210 feet away. The water from this well yielded typhoid bacillus and coliform. The soil in the area was extremely pervious gravel and at the time of the outbreak the groundwater level was at or near its seasonal peak[1].

Shigellosis

Between January and March, 1974, 1200 cases of shigellosis occurred in Richmond Heights, Florida, which is a residential community of 6500 persons. It was found that one of the two wells providing water to the community had been continuously contaminated with excessive levels of fecal coliform. The source of contamination was traced by dye studies to the septic tank of a church and a day care center located approximately 150 feet from the well. A breakdown in chlorination allowed about one million gallons of unchlorinated or insufficiently chlorinated water from the contaminated well to be distributed to the community 48 hours before the epidemic began[1].

A large outbreak of shigellosis occurred in July 1987 among persons attending the annual Rainbow Family gathering, held that year at the Nantahala National Forest in North Carolina. Over 6,000 attendees were infected due to poor hygiene and inadequate trench latrines. Frequent rainfall during the event contributed to the propagation and transmission of the disease[21].

During 1995-1996, in Colorado, a lake contaminated with human feces caused a total of 120 persons to become ill with shigellosis in two outbreaks[11].

Bacterial Gastroenteritis

An outbreak caused by *E. coli* O157:H7 in 1991, may have involved recreational lake water in the vicinity of Portland, Oregon. Those who became ill had swum in the lake during the previous 3-week period. Transmission probably occurred when the swimmers swallowed lake water that was fecally contaminated. By swallowing a small amount of lake water, can cause illness suggests that the pathogen has a low infectious dose[5].

In July 1995, an outbreak of *E. coli* O157:H7 was reported among children in Rockford, Illinois. Interviews of the children's parents revealed no common food source, however, on June 24-25, they all had visited an Illinois state park with a lake swimming beach. It was indicated that the children were infected by ingesting contaminated lake water[15].

In August 1995, an outbreak of *E.coli* O157:H7 occurred at a summer camp in Minnesota that was supplied by chlorinated spring water. Several of the 33 affected persons had stool cultures that also were positive for *Campylobactor jejuni* and *Salmonella* serotype London. Water samples from the spring and distribution system were positive for coliform and *E. coli*. The contamination was attributed to flooding from heavy rains and to an improperly constructed spring[11].

Pseudomonas Folliculitis

In May 1983, an outbreak of *Pseudomonas* Folliculitis occurred among 650 persons who visited a water slide in Salt Lake City County, Utah. Samples taken from papulovesicular lesions of patients for culture and antibiotic sensitivity testing were positive for *Pseudomonas aeruginosa*. Drainage from the ears of exposed individuals also grew *P. aeruginosa*, as did multiple environmental samples from the water. Showering within 30 minutes after exposure did not reduce the risk of developing a rash. This was the first outbreak associated with a water slide. Warm and humid conditions combined with ineffective chlorination probably led to the growth of *P. aeruginosa* in the pool[16].

Cryptosporidiosis

In 1995, 47 cases of cryptosporidiosis were reported in England. Upon investigation a strong correlation between the location of the cases and two wells was established. Both well shafts were in the same aquifer. One well was improperly sited such that during heavy rainfall it received surface runoff from a nearby grazing pasture. The lining of the other well showed signs of corrosion. This well was found to be short-circuited with a nearby soil absorption field. The geology of the aquifer is sandstone, which apparently is somewhat karstic[10].

In 1993, a massive cryptosporidiosis outbreak occurred in Milwaukee, Wisconsin, causing 104 deaths and 403,000 ill persons. This outbreak illustrated the magnitude of the public health consequences when *cryptosporidium* is transmitted through a municipal water system[9].

Giardiasis

In spring 1988, a giardiasis outbreak occurred among a church youth group in Albuquerque, New Mexico. The church was on the municipal water system. A survey of possible connections between the church's potable water system and the sanitary sewer system identified five potential cross-connections[19].

The largest giardiasis outbreak for the reporting period, 1995-1996, in New York, was associated with surface water that was filtered and disinfected with chlorine. Although no interruptions in chlorination at the water plant was identified, postfilter water turbidity readings, which serves as an index of the effectiveness of filtration exceeded the regulated limit before and after the outbreak. This demonstrates that *Giardia* remains a public health risk even in chlorinated and filtered water systems, if levels of water turbidity are not consistently maintained[11].

Health Problems caused by Chemicals

Waste from industries is often responsible for the chemical pollution. However, contaminants such as nitrates and certain toxic organic compounds from OSDS can contribute to chemical pollution.

Nitrates

Nitrate in domestic wastewater is one of the contaminants which has been receiving more attention in recent years. Most of the nitrogen in septic tank effluent is converted to nitrate in the OSDS treatment process. Nitrates move readily through the soils and may contribute to elevated nitrate levels in groundwater and eutrophication in surface waters.

The most recognized health problem due to high levels of ingested nitrates is methemoglobinemia or blue baby syndrome, which can affect infants. In this syndrome, ingested nitrate is reduced to nitrite in the digestive tract. The nitrite is then absorbed into the bloodstream, where it produces methemoglobin, a form of hemoglobin that can not carry oxygen. Infant deaths from this disease are unlikely where nitrate concentrations in drinking water are less than 10 mg/l. Although deaths from methemoglobinemia are rare in the United States, at least one infant died in 1986 from drinking formula made with water from a nitrate-contaminated well[28].

Other health effects that may be associated with nitrates in drinking water include impairment of the nervous system, cancer and birth defects[28].

A random sampling of 200 wells on Long Island, New York, showed that nitrate concentrations in the upper aquifer averaged about 6 mg/l but exceeded 22 mg/l in several places. Similar observations were reported from studies conducted in Boston, Los Angeles, Delaware and Connecticut. These studies indicated that the OSDS in the area were the source of contamination of groundwater[28].

Eutrophication is the degradation of surface water due to increased growth of algae. This growth is encouraged by the high nitrate concentration in drainage and runoff water received by the surface water. As the algae growth is increased, the dissolved oxygen in water is decreased. Surface water becomes polluted as the anaerobic bacterial growth is increased due to the decline in dissolved oxygen in water.

High concentrations of nitrogen and phosphorus, which come largely from either sewage discharges or animal waste, act as fertilizers for microscopic plants. These single-celled organisms multiply rapidly and form blooms that can last for days or months. Of the thousand species of these organisms, 63 are known to be toxic to animals and humans. Depending on the type of the toxic organism, beachgoers can experience a host of illness ranging from respiratory problems, eye irritations to neurotoxic poisoning that can cause short-term memory loss, dizziness, muscular aches, peripheral tingling, vomiting and abdominal pain. Although the most common type of poisoning related to toxic blooms is from eating contaminated shellfish, there were numerous instances where such blooms affected fishermen, swimmers and other recreational users of nearshore marine and riverine waters[23].

In 1995, a section of the Neuse River in North Carolina was closed for more than two weeks as the result of a large fish kill where *Pfiesteria piscicida* was found in large concentrations. Several waterways in Maryland were closed for weeks in 1997 for the same reason[23].

Toxic organic chemicals

The most prevalent toxic organic chemicals found in domestic wastewater are from household products such as solvents, cleaners, and perfumes. These include toluene, xylene, 1,1,1-trichloroethane, and acetone. In general, many of the synthetic organic compounds are more mobile and less susceptible to biological and chemical degradation than microbiological and inorganic contaminants. Although sold in more diluted formulations than used in industry, household hazardous chemicals can persist in the environment for a long time[7]. The accumulation of small quantities of toxic chemicals from millions of households could reach a dangerous level and become a vital public concern. Household chemicals poured down the drain could pose an immediate health threat, especially if an OSDS is used and the homeowner relies on local groundwater for drinking supplies.

Septic tank additives are used to maintain tank efficiency, although their use is not recommended. Tanks should be installed and maintained properly without the use of additives. They operate by dissolving the accumulated sludge, allowing both the additive and the sludge solution to enter into the absorption field. Some additives contain TCE (trichloroethylene), benzene or methylene chloride, chemicals that should not come into contact with drinking water[28].

Homeowners on Long Island in1979 used approximately 400,000 gallons of septic tank additives. Widespread groundwater contamination resulted, leading to the closure of many private and public wells[28].

The health effects of toxic chemicals can be either acute or chronic. Acute effects occur as a result of contact with high levels of a chemical over a short time period. These include nausea, skin irritation, central nervous system damage, and, in some cases, death. Chronic effects generally occur as a result of long term exposure, at a lower level. These include cancer, mutations, birth defects, and immunological problems. Many chronic health problems such as headaches, mood changes or respiratory problems have numerous causes. So it is difficult to associate such a general effect with a specific waterborne chemical[28].

Removal of Pathogens in Soil Absorption Field

The removal of pathogens in the soil absorption field is determined by four factors.

1. Nature of the pathogen
2. Climate
3. Soil properties
4. Topography

Nature of the pathogen

The greatest removal of pathogens occurs in the biological mat at the interface of the soil in the soil absorption field. Only a few inches thick in a properly functioning OSDS, the biological mat serves as a filter, by which the majority of larger organisms are entrained. Ideally, the biological mat is unsaturated and aerobic. This creates an ecological niche in which the facultative anaerobic bacteria in the effluent are at a competitive disadvantage. Pathogens entrained or attached to the matrix may be consumed or out competed for nutrients by established microflora. Certain agents including most viruses, spore-forming bacteria, protozoa cysts, and helminth eggs are very persistent and are not easily degraded in the biological mat[1].

Climate

Temperature and rainfall are two important factors controlled by the climate. Cool temperatures (1-4 ^{0}C or 34-39^{0}F) enhance the survival of pathogens. At higher temperatures (5-30^{0}C or 41-86^{0}F) inactivation or die-off is fairly rapid. Temperature is the critical factor that determines pathogen survival above 30^{0}C or 86^{0}F. Also, freezing temperatures (<1^{0}C or <34^{0}F) may decrease their survival. Rainfall mobilizes retained pathogens and promotes their transport through soil pores to groundwater[1].

Soil properties

Soil properties influence the moisture holding capacity, pH and organic matter content, which control the survival of the agents in the soil. Pathogens survive longer under moist conditions. As soil moisture levels decrease the agents may be inactivated by desiccation. Bacteria and viruses persist better in alkaline soils, whereas in acid soils, their adsorption reaches its maximum. Organic matter has been shown to increase the survival of certain bacteria and viruses in soil. Other soil properties such as soil particle size, cation exchange capacity, and clay content influence their retention[1]. High sand content soils may be too permeable, thus increasing the potential of groundwater contamination. Clayey soils, on the other hand, may not allow enough drainage, thus creating saturated and possibly anaerobic conditions[10].

Topography

Slope and location of bodies of water must be considered. A steep slope may increase the flow rate through the soil decreasing the adsorption of pathogens. Nearby bodies of water may lead to seasonal saturated conditions, favoring pathogen movement through the soil[10].

In considering groundwater contamination from OSDS, attention must be directed to transport and fate of pollutants from the soil absorption field through underlying soils and into the groundwater. The most comprehensive study on soil absorption of effluents has been conducted by the Small Scale Waste Management Project Group at the University of Wisconsin. Filtration of bacteria was determined by dissecting a soil absorption field and enumerating indicator organisms present in the soil at various distances below the soil absorption field trench. The large population of total coliform, fecal coliform and enterococci present in the septic tank effluent were reduced to levels associated with control soil samples within 24 inches below the trench[1].

There is insufficient information regarding virus movement from onsite sewage disposal systems. Green and Cliver described mound systems with sand, which was efficient in the removal of poliovirus. They detailed the essential design criteria such as dose rate, fill thickness, operation temperature and system conditioning that must be considered for effective virus removal. With proper design and operation, mounds incorporating 24 inches of sandy fill yielded effluents that presented no health hazards from viruses[1].

Removal of Nitrates

Most of the nitrogen in the effluent of an OSDS is converted to nitrate. Therefore, in areas which are susceptible to elevated nitrate levels of about 10 mg/l of groundwater, pretreatment methods to remove nitrate is recommended. Nitrogen from nitrate in effluent could be released as gaseous nitrogen using biological or chemical processes, before it reaches the soil absorption field.

Conclusion

Contamination of groundwater and nearby surface waters by pathogens from OSDS is a public health threat. OSDS must be properly sited, designed, constructed, operated, and maintained to ensure adequate long-term performance in treating pathogens and other contaminants in domestic wastewater. With proper state and local programs, education and training programs, and qualified personnel such as environmental health specilists, soil scientists and installers, OSDS can be designed, constructed and operated to provide an effective and efficient means of sewage disposal without risk to public health.

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Table 1. Major pathogens associated with domestic wastewater

Agent	Major disease
Viruses	
Hepatitis A virus	Hepatitis A
Polioviruses	Poliomyelitis
Rotaviruses	Gastroenteritis
Norwalk-type viruses	Gastroenteritis
Adenoviruses	Gastroenteritis
Reoviruses	Gastroenteritis
Coxackieviruses	Meningitis
Echoviruses	Meningitis
Arboviruses (transmitted by *Culex* mosquitoes)	Encephalitis
Bacteria	
*Salmonella typhi_*	Typhoid fever
Salmonella paratyphi	Paratyphoid fever
Other *Salmonella Sp.*	Gastroenteritis
Shigella sonnei	Shigellosis
Other *Shigella sp.*	Shigellosis
Enteropathogenic *Escherichia coli*	Gastroenteritis
Campylobactor jejuni	Gastroenteritis
Yersinia enterocolitica	Gastroenteritis
Vibrio cholerae	Cholera
Other *Vibrio sp.*	Gastroenteritis
Helicobactor pylori	Gastritis
Pseudomonas aeruginosa	Folliculitis
Protozoas	
Cryptosporidium parvum	Gastroenteritis
Giardia lamblia	Giardiasis
Entamoeba histolitica	Amoebic dysentery
Balantidium coli	Dysentery
Helminths	
Ascaris lumbricoides (large roundworm)	Pneumonitis and gastroenteritis
Trichuris trichiura (whipworm)	Chronic gastroenteritis
Ancylostoma duodenale (old world hookworm)	Chronic anemia
Necator americanus (new world hookworm)	Chronic anemia
Taenia saginata (beef tapeworm)	Taeniasis

Table 2. Major toxic organic chemicals in domestic wastewater

Contaminant	Toxic Effects
Trichloroehylene (TCE)	Cancer, central nervous system disorder, heart, kidney and liver damage, respiratory, and blood cell disorders, skin irritation
Benzene	Nervous system disorder, cancer, immunological and gastrointestinal disorders, eye and skin irritation, allergic sensitization
Toluene	Central nervous system disorder, heart, kidney and liver damage, upper respiratory tract, eye and skin irritation
1,1,1-trichloroethane	Cancer, birth defects, central nervous system disorder, kidney, liver, and respiratory disorder, eye and skin irritation