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Project Summary

Potential Health Effects from Viable Emissions and Toxins Associated with Wastewater Treatment Plants and Land Application Sites

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This study presents an overview of the literature on potential health effects from viable emissions and toxins associated with wastewater treatment plants and land application facilities to the workers and nearby populations. The different types of microorganisms present in wastewater and sludge and the effectiveness of the various treatment processes in their removal or inactivation is discussed briefly. The monitoring of microorganisms and toxins in aerosols generated at wastewater treatment plants and land application sites, the disadvantages in using coliform organisms as indicators to represent the actual levels of pathogenic microorganisms in aerosols, and the various mathematical models that are used to predict the microorganism levels in aerosols are also reviewed. The levels of microorganisms detected in aerosols at wastewater treatment plants and land application facilities from some of the recent studies are presented.

This Project Summary was developed by EPA's Health Effects Research Laboratory, 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

A large variety of potential disease-causing microorganisms and viruses are present in municipal wastewaters. Wastewater treatment plant workers are potentially exposed to these pathogenic microorganisms and viruses through ingestion as well as inhalation of the aerosolized pathogens. Residents of nearby wastewater treatment plants may be exposed to low densities of these pathogenic microorganisms and viruses that become airborne.

Land application of wastewater and sludge is gaining renewed interest as an alternative means to the more conventionally used disposal methods, such as ocean and surface water dumping, and incineration. Land application represents a recycling process in which water and plant nutrients are returned to the soil. However, wastewater treatment does not completely remove pathogens and many become concentrated in the sludge.

Exposure to airborne pathogens and toxins can affect the health of workers at wastewater treatment plants and land application sites, and on the populations living in the vicinity of the treatment plants and land application sites. Precautions should be taken to limit human exposure to these airborne pathogens and toxins.

Information regarding human health risks resulting from contact with wastewater and sludge brought about by occupational exposure or by residing near wastewater treatment plants and/or land application facilities is limited. Several health effects studies have been initiated in the past few years on the health risks of pathogens in wastewater and aerosols generated at the wastewater treatment plants.

Discussion

Microorganisms. The major groups of microorganisms present in municipal wastewater and sludge are bacteria, viruses, protozoa, and helminths. Some of these microorganisms, the diseases that are attributed to them, and known reservoirs of infection are shown in Table 1.

Toxins. The dust generated at the wastewater treatment plants during sludge heat-treatment operations and at land application sites may contain significant quantities of toxins which may represent a potential health risk to the workers. The toxins of concern are endotoxins derived from bacteria and mycotoxins produced by the fungi.

Wastewater and Sludge Treatment. Primary treatment involves physical processes, such as screening, grit removal, and sedimentation in which the microorganisms may settle out by their density or by being adsorbed to solids. Because of their relatively small size, viruses are less easily removed from wastewater than bacteria, protozoa, or helminths. Secondary treatment is a biological degradation process. Activated sludge treatment, trickling filters, aerated lagoons, and ponding are some of the secondary treatment processes. Chemical treatment, filtration, adsorption, ion exchange, and nitrogen removal are forms of tertiary treatment processes. Information on survival of microorganisms during tertiary treatment processes is limited. Indications are that microorganisms are not completely removed by tertiary treatment. Chlorination and ozonation are two of the methods used for the disinfection of wastewater effluents, of which chlorination is most commonly used.

Each of the above mentioned sedimentation processes produces a sludge. Stabilization of sludge by treatment prior to land application is usually necessary to reduce the levels of pathogenic microorganisms and decomposible organic matter. Anaerobic digestion, aerobic digestion, chemical treatment, heat-drying, and composting are some of the methods that can be used to stabilize the sludge.

The existing data indicate that some of the microorganisms survive during wastewater and sludge treatment. Also, the amount of endotoxins may increase during treatment processes that result in destruction of bacteria. Workers at wastewater treatment plants and land application sites will, therefore, be potentially at risk of exposure to pathogenic bacteria, viruses, and endotoxins.

Aerosols. Some of the microorganisms present in wastewater and sludge, especially bacteria and viruses, can become airborne. Major sources of the aerosols are the aeration basin of the activated sludge treatment units, trickling filters, and land application sites that use spray irrigation. Aerosols are particulate materials in either solid or liquid form and may also include gases and vapors that are adsorbed or contained in airborne particles or liquid droplets. Inhalation is a possible route of infection because the viruses and most pathogenic bacteria are in the respirable size range. The health hazard posed by aerosolized particles depends on their ability to deposit in the lungs.

Airborne microorganisms are usually collected for sampling by the Andersen air sampler, all glass impinger, or high volume air sampler Viruses in aerosols are less well studied than bacteria, mainly due to technical limitations in sampling and in obtaining accurate measurement of viruses in air. Large volumes of air must be sampled for virus monitoring in aerosols due to the low levels of viruses present in wastewater and wastewater aerosols.

Coliform bacteria and coliphage viruses are generally used as indicators of fecal contamination in water, since they are considered to reflect pathogen levels. Coliform organisms do not survive wastewater aerosolization as well as other microorganisms. Therefore, they have limited usefulness as indicators of pathogens in aerosols. The use of coliform organisms as indicators would tend to underestimate the potential effect on workers as well as nearby populations. One of the limitations to the accurate monitoring of endotoxin levels in environmental samples is the lack of a sensitive and specific assay for endotoxins.

Wastewater application methods play an important role in the emission of aerosols at land application sites where spray or sprinkler irrigation is believed to generate the maximum amount of aerosols. Microbial concentration in aerosols would depend on the degree of treatment received by the wastewater or the sludge; concentration decreasing as the treatment process increases. Available data indicate that microorganisms in aerosols generated at spray irrigation sites may remain viable and be dispersed for several hundred meters from the spray source.

Some of the variables that affect the survival and dispersion of microorganisms in aerosols are die-off, deposition, and diffusion. These in turn are affected by the following environmental factors; relative humidity, wind velocity, sunlight, temperature, and actual field conditions compared to controlled conditions in the laboratory.

Several theoretical mathematical dispersion models for predicting the microorganism levels in aerosols have been developed in recent years. A valid model is used to estimate airborne pathogen levels at any location downwind of a source of microbial aerosols, which could also be used to predict pathogenic microoganism exposure. However, it should be pointed out that the exact health risks cannot be determined until the threshold levels for aerosolized pathogens resulting in health effects are established. Comparison of the threshold levels with the predicted and actual airborne values of microorganisms would permit the determination of the health risks associated with aerosols at a given facility, and would be invaluable in planning future treatment sites. Further predicted concentrations and their predicted associated risks could be used to help set standards for emissions at treatment facilities, if needed. To date, dispersion models have limited usefulness in the prediction of aerosol concentrations of microorganisms. Further research is needed to test and improve present models or to develop new ones.

Because of the lack of a standard method for viral monitoring, the comparison of data from two or more laboratories must take into consideration differences in sample handling, concentration, and method of measurement. Due to the difficulties involved in routinely detecting airborne viruses at

Table 1. *Major Organisms of Health Concern That May be Present in Sewage from U.S. Communities*

Organisms	Disease	Reservoir(s)
I. BACTERIA		
Salmonellae (Approx. 1700 types)	*Typhoid fever Salmonellosis*	*Man, domestic and Wild animals and birds*
Shigellae (4 spp.)	*Shigellosis (bacillary dysentary)*	*Man*
Escherichia coli *(enteropathogenic types)*	*Gastroenteritis*	*Man, domestic animals*
II. ENTERIC VIRUSES		
Enteroviruses (67 types)	*Gastroenteritis, heart anomalies, meningitis, others*	*Man, Possibly lower animals*
Rotavirus	*Gastroenteritis*	*Man, domestic animals*
Parvovirus-like agents (at least 2 types)	*Gastroenteritis*	*Man*
Hepatitis A virus	*Infectious hepatitis*	*Man, other primates*
Adenoviruses (31 types)	*Respiratory disease, conjunctivities, other*	*Man*
III. PROTOZOAN		
Balantidium coli	*Balantidiasis*	*Man, swine*
Entamoeba histolytica	*Amebiasis*	*Man*
Giardia lamblia	*Giardiasis*	*Man, domestic and wild animals?*
IV. HELMINTHS		
Nematodes (Roundworms)		
Ascaris lumbricoides	*Ascariasis*	*Man, swine?*
Ancylostoma duodenale	*Ancylostomiasis*	*Man*
Necator americanus	*Necatoriasis*	*Man*
Ancylostoma braziliense *(cat hookworm)*	*Cutaneous larva migrans*	*Cat*
Ancylostoma caninum *(dog hookworm)*	*Cutaneous larva migrans*	*Dog*
Enterobius vermicularis *(pinworm)*	*Enterobiasis*	*Man*
Strongyloides stercoralis *(threadworm)*	*Strongyloidiasis*	*Man, dog*
Toxocara cati *(cat roundworm)*	*Visceral larva migrans*	*Carnivores*
Toxocara canis *(dog roundworm)*	*Visceral larva migrans*	*Carnivores*
Trichuris trichiura *(whipworm)*	*Trichuriasis*	*Man*

Table 1. *(continued)*

Cestodes (Tapeworms)		
Taenia saginata *(beef tapeworm)*	*Taeniasis*	*Man*
Taenia solium *(pork tapeworm)*	*Taeniasis*	*Man*
Hymenolepis nana *(dwarf tapeworm)*	*Taeniasis*	*Man, rat*
Echinococcus granulosis *(dog tapeworm)*	*Unilocular Echinococcosis*	*Dog*
Echinococcus multilocularis	*Alveolar hydatid disease*	*Dog, carnivore*

wastewater treatment plants and spray irrigation facilities, it is presently not possible to validate atmospheric dispersion models for their prediction. For bacteria, the models appear to have some usefulness, but have not been perfected enough to replace the field monitoring.

Health Effects. Pathogenic microorganisms generated at wastewater treatment plants and land application sites can be transmitted via inhalation, skin contact, and ingestion. Infection may result in disease, depending on the degree of exposure as well as other factors, such as pathogen density, minimum infective dose, virulence of the organism, and susceptibility of the exposed individual. Under special circumstances an infection can develop from a single virus, protozoan, or helminth. The minimum infective dose for bacteria ranges from 100 to 100 million, depending on species. Information is not available on minimum infective dose of airborne microorganism levels for the inhalation route.

A number of epidemiological studies have recently been performed on workers at wastewater treatment plants and spray irrigation facilities, and on populations living adjacent to these sites who would generally be exposed to lower levels of the pathogens. Data on health effects from the existing epidemiological studies do not show any correlation between the airborne pathogenic microorganism levels at wastewater treatment plants and incidence of disease in treatment plant workers or in nearby populations. However, the worst case of exposure of either the workers or the nearby populations has probably not yet been investigated. No adverse health effects have been reported in workers or in nearby populations at wastewater spray application facilities. The data on health effects from the existing epidemiological studies concludes that exposure to pathogenic microorganisms in wastewater aerosols is not a unique way of initiating enteric infections. The existence of the other possible pathways of infection could make the detection of a wastewater facility effect more difficult, if indeed one exists. There is, however, a potential for contamination of food crops grown on wastewater or sludge treated lands. This should be taken into consideration when formulating guidelines or recommendations.

Aerosol Control. A number of techniques have been investigated to control or suppress aerosols and/or the levels of microorganisms in aerosols. Vegetative barriers have been implemented for aerosol suppression resulting in a 50% reduction of microorganisms in aerosols. Strategically-placed vegetation could effectively reduce aerosols generated at wastewater treatment plants and at spray irrigation facilities. Buffer/safety zones are areas between the wastewater treatment plant or the edge of the wetted area of the spray irrigation site and adjacent land uses that ensures adequate protection of populations from potential health hazards or aesthetic insult of exposure to pathogenic microoganisms in aerosols. These zones also protect water supplies from contamination with pathogenic microorganisms present in wastewater and sludge used for land application. Disinfection of wastewater prior to spray application has been shown to reduce the levels of airborne microorganisms to nondetectable levels. Proper spray equipment design and the use of subsurface injection have also been shown to effectively reduce the generation of aerosols. Covering aeration basins will effectively suppress aerosols as well as control odors. These measures could serve to control the exposure of nearby populations, and in some cases, but to a lesser extent, that of the workers. Data from viral and bacterial monitoring of wastewater and aerosols indicate that buffer or safety zones may not be necessary between wastewater treatment plants or spray application facilities and the surrounding population centers.

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The complete report, entitled "Potential Health Effects from Viable Emissions and Toxins Associated with Wastewater Treatment Plants and Land Application Sites," (Order No. PB 81 - 145 260; Cost: $9.50, subject to change) will be available only from:
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