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HETA 98–0118–2748
Bio–Solids Land Application Process
LeSourdsville, Ohio

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Douglas Trout, M.D., M.H.S.

PREFACE

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Nancy Clark Burton and Douglas Trout of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Kenneth F. Martinez and Robert McCleery from DSHEFS, and Sunny Grosz from the Division of Physical Sciences and Engineering (DPSE). Analytical support was provided by PathCon Laboratories, Data Chem Laboratories, and the NIOSH Health Effects Laboratory Division. Desktop publishing was performed by Ellen E. Blythe. Review and preparation for printing was performed by Penny Arthur.

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August 1999

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SUMMARY

In February 1998, the National Institute for Occupational Safety and Health (NIOSH) received a health hazard evaluation (HHE) request from management asking for assistance in evaluating workers' exposures during the land application of biosolids (treated sewage sludge) at the Butler County Department of Environmental Services, LeSourdsville, Ohio, facility. The HHE request stated that some employees had reported headaches, stomach cramps, and diarrhea. In response to this request, an initial site visit was conducted on March 17, 1998, to look at the production process and to interview the employees who work directly with the land application process. During that site visit, all five employees performing work related to biosolids application were interviewed. Additional site visits were made on April 3 and July 9, 1998, to gather information on the wastewater treatment plant and land application processes. Environmental monitoring was conducted on August 5, 1998, which included the collection of area and/or personal breathing zone air samples for culturable bacteria, endotoxins (a component in cell membranes of Gram–negative bacteria), volatile organic compounds (VOCs), and trace metals. Bulk samples of sewage sludge were analyzed for coliform bacteria.

In the interviews, all five employees reported at least one episode of gastrointestinal illness occurring soon after working with the biosolids (either at the treatment plant or during the land application), and four reported repeated intermittent episodes of various gastrointestinal symptoms including diarrhea and abdominal cramping.

For 18 sample sets, the geometric mean bacterial air area concentrations ranged from 412 to 2,356 colony forming units per cubic meter of air (CFU/m^3). All of the bacterial genera identified from these samples are associated with outdoor environments or mammals. Some of the bacteria found in the samples are opportunistic human pathogens such as *Mycobacterium*, *Pseudomonas*, and *Staphylococcus*. Airborne endotoxin levels ranged from 20 to 39 endotoxin units per cubic meter (EU/m^3), which are similar or below levels found in wastewater treatment plants. The geometric mean concentration of coliform bacteria in the bulk sewage sludge samples was 2.7×10^4 CFU per gram of sample. The geometric mean concentration of *Escherichia coli* from the bulk samples was 2.2×10^4 CFU per gram of sample. The concentrations of various metals (aluminum, barium, iron, manganese, nickel, silver, and titanium) and VOCs, including toluene, were low and well below current occupational exposure limits.

The detection of enteric bacteria in the air and bulk samples collected during this evaluation indicates a potential for occupational exposure to disease–causing organisms. While the specific component(s) of the sewage sludge responsible for employees' symptoms have not been determined, the nature and timing of the symptoms suggest occupational exposure by ingestion or inhalation of the sludge as a probable cause. Recommendations for minimizing the growth of microorganisms during the sewage sludge storage process, increasing the usage of hygienic practices and personal protective equipment, and minimizing occupational exposure to the microorganisms are included in this report.

Keywords: SIC Code 4952 (Sewerage Systems), sewage sludge, biosolids, fecal coliform, gastrointestinal illnesses, Class B sludge, pathogens, trace metals, volatile organic compounds, VOCs, endotoxins.

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INTRODUCTION

In February 1998, the National Institute for Occupational Safety and Health (NIOSH) received a health hazard evaluation (HHE) request from management asking for assistance in evaluating workers' exposures during the land application of biosolids (treated sewage sludge) at the Butler County Department of Environmental Services, LeSourdsville, Ohio, facility. The HHE request stated that some employees had reported headaches, stomach cramps, and diarrhea. In response to this request, an initial site visit was conducted on March 17, 1998, to look at the production process and to interview the employees who work directly with the land application process. During that site visit, all five employees working in the biosolids application area were interviewed. A site visit was made on April 3, 1998, to observe the truck loading procedure and the spreading and incorporation of the sewage sludge in the farm fields, and another site visit was conducted on July 9, 1998, to gather information concerning the operation of the wastewater treatment plant. Environmental monitoring was conducted on August 5, 1998. An interim letter was provided in July 1998.

BACKGROUND

The LeSourdsville wastewater treatment plant handles six to seven million gallons of wastewater each day. Typically, the wastewater that enters the plant passes through two sets of screens that remove large items and most of the other solid material. The incoming wastewater is tested for metal content. The solid materials collected from the screens go through a conveyor system to a collection bin and are disposed of in a landfill. The wastewater is pumped to an "oxygen" ditch, where microorganisms are added as part of the aerobic digestion process. This facility uses aerobic digestion to inhibit the growth of pathogenic microorganisms by reducing the organic content of the sewage sludge, which serves as the organisms' food supply. The facility is mostly automated, with mechanical mixers and sensors that measure dissolved oxygen and other parameters. The wastewater stays in this digestion area for 18 to 32 hours, depending upon specific criteria including ammonia removal and nitrification. The wastewater goes through splitter boxes into two final clarifiers, in which the fine particles settle to the bottom and the water is drawn off the top. The fine particle solids go through a digester system for 6 to 12 days until the fecal coliform levels reach an acceptable level. Water is again drawn off the top, undergoes disinfection with ultraviolet irradiation, and is discharged into the river. The solids are pumped to the dewatering building, where a polymer is added and the resultant material goes through a belt filter press. The water is returned to the wastewater treatment system. The solids feed into a conveyor system which deposits them into a truck. The truck takes the sludge (15–20% solids) to a concrete pad with a roof and partial walls.

The sewage sludge is stored until there is enough material to apply to the farm fields. The sewage sludge can also be landfilled if conditions are not favorable to spread the sludge. According to U.S. Environmental Protection Agency (EPA) regulations, seven samples of treated sewage from the material to be land–applied should be collected and analyzed for fecal coliform bacteria.[1] The geometric mean fecal coliform density has to be less than 2 million colony forming units (CFU) per gram of total solids (dry weight) before the biosolids can be used.[2] The LeSourdsville facility operates under U.S. EPA Class B restrictions for sewage sludge, which still has measurable levels of pathogens. Large dump trucks are loaded at the concrete pad by the truck drivers using a front–end loader. The truck drivers have leather gloves but use them intermittently. Three trucks were used during the August site visit; each truck carries 11.7 tons of biosolids per trip. The trucks are driven to a farm field and dumped. At the farm, a front–end loader is used to load the side discharge sludge spreader. The sludge spreader operator sprays the sludge on the field and, usually, a separate tractor operator disks (incorporates) it into the soil.

The facility has been land applying biosolids since 1996. Sewage sludge from the Upper Mill Creek wastewater treatment plant is trucked to the LeSourdsville facility and added to the concrete pad so it can also be field–applied. Five employees, including a supervisor and four biosolids operators, perform work related to biosolids land application. Job duties are rotated so that each employee may perform the tasks as needed. The employees have other duties around the wastewater treatment plants when they are not land–applying biosolids.

METHODS

Culturable Bacteria

To determine concentrations of culturable airborne bacteria, an Andersen single–stage viable cascade impactor was used at a calibrated flowrate of 28.3 liters per minute (Lpm). Samples were collected at the concrete pad during the loading of the trucks, at the farm fields during dumping and land applying the biosolids, at a farm field next to the treated field, and next to the wastewater discharge into the river. The Andersen single–stage impactor is designed to collect particles 0.65 micrometers (µm) or larger. Samples were collected in sets of two replicates using R2Ac agar for environmental bacteria (also human commensal bacteria) and McConkey agar for the isolation of human commensal bacteria. Nine sets of duplicate samples were collected at the concrete pad and the farm field during various work activities. All samples were collected over a total three–minute time period (one–minute and two–minute agar plates were collected and the results combined). The samples were shipped overnight to the contract laboratory. R2Ac sample plates were incubated at room temperature and McConkey sample plates were incubated at 35°C. The taxa and rank of the collected microorganisms were determined by morphological characteristics.

Seven bulk samples of sewage sludge were collected at various locations in the sludge pile on the concrete pad. The samples were analyzed for general coliform bacteria and *Escherichia coli* (*E. coli*) bacteria using the Petrifilm *E.Coli*/coliform method.

Endotoxin

Two personal breathing zone (PBZ) and three area air samples were collected for endotoxin (component in cell walls of Gram–negative bacteria). The samples were collected on two truck drivers, at the concrete pad, and in the cabs of the equipment in the farm fields. The samples were collected on tared 5.0– µm pore size, 37– millimeter (mm) polyvinyl chloride filters using a calibrated flowrate of 2 Lpm. The samples were weighed[3] and analyzed for endotoxin content using the Kinetic–QCL assay kit (BioWhittaker, Walkerville, Maryland) according to the manufacturer's recommended procedures. For these analyses, 10 endotoxin units (EU) are equivalent to one nanogram of endotoxin. The limit of detection (LOD) for the analyses was 0.5 EU per sample, which results in a minimum detectable concentrations (MDC) of 1.3 EU/m^3, using a sample volume of 383 liters.

Metals

Four area air samples were collected for selected metals on mixed–cellulose ester filters (37–mm diameter, 0.8–µm pore size) using a flowrate of 2.0 Lpm. The samples were collected at the concrete pad and in the cabs of the equipment in the farm fields. The filters were placed in a microwave digestion vessel with a 1:1 solution of water and nitric acid. The vessels were sealed and digested in a microwave. The samples were transferred to flasks and diluted to volume with water. The resultant sample solutions were analyzed for metals according to NIOSH Method 7300,[4] modified for microwave digestion, using inductively coupled plasma–atomic emission spectrometry. The MDCs and minimum quantifiable concentrations (MQCs) for the detected metals are listed in Table 5. The method can detect the following elements–aluminum, arsenic, barium, beryllium, calcium, cadmium, cobalt, chromium, copper, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, phosphorus, platinum, selenium, silver, sodium, tellurium, thallium, titanium, vanadium, yttrium, zinc, and zirconium.[4]

Volatile Organic Compounds

Four area air samples were collected around the perimeter of the concrete pad to estimate worker exposures to volatile organic compounds (VOCs) coming from the sludge pile during the truck loading process. The samples were collected on thermal desorption tubes which contained three beds of sorbent material. The samples were analyzed using a Perkin–Elmer ATD 400 thermal desorption system with an internal focusing trap packed with Carbopack B/Carboxen 1000 sorbents. The thermal unit was interfaced directly to a gas chromatograph with a mass selective detector (TD–GC–MSD). Sample tubes were dry purged with helium to remove water.

Medical Interviews

Personal interviews were conducted with the five employees working in the biosolids application area to gather information on health status and work practices.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre–existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increases the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[5] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[6] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[7] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm.[8] Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short–term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

A time–weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8–to–10–hour workday. Some substances have recommended STELs or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short–term.

Health Hazards Associated with Sewage Sludge

Sewage sludge, also called wastewater residuals, has been used as a fertilizer and soil conditioner in the U.S. for several years. Biosolids is another name for the beneficial treated residuals from wastewater treatment. The use and disposal of sewage sludge in the U.S. is regulated under 42 CFR Parts 257, 403, and 503 – Standards for the Use or Disposal of Sewage Sludge: Final Rules.[1] The U.S. EPA is the lead agency that has regulatory responsibilities for wastewater treatment and sewage sludge disposal.

Pathogens

There are four major types of human pathogenic organisms found in sewage sludge: (1) bacteria, (2) viruses, (3) protozoa, and (4) helminths (parasitic worms).[2] The levels of pathogens present in the sewage sludge depend upon the number of microorganisms present in the waste stream and the reduction of pathogenic organisms achieved by the wastewater and sewage treatment processes. Examples of pathogens potentially found in wastewater and sewage sludge are presented in Table 1. Several of these pathogens can cause gastrointestinal illnesses. Some are present infrequently, depending, in part, on geographic area.

There are two separate pathogen reduction requirements for sewage sludge–Class A and Class B.[2] The goal of Class A requirements is to reduce pathogen levels to below detectable limits. The goal of Class B requirements is to reduce the level of pathogens to concentrations that are unlikely to pose a health risk to the public and the environment. There are site restrictions for land application of Class B sludge. Crop harvesting, animal grazing, and public contact are limited to allow environmental factors to further reduce pathogen levels.

Some epidemiological studies of wastewater and sewage workers have shown an increased risk of gastrointestinal symptoms.[9,10,11,12,13] Lundholm and Rylander found that skin disorders, diarrhea, and other gastrointestinal symptoms were more prevalent among employees at six Swedish wastewater treatment plants than among workers at three water treatment plants.[14] Scarlett–Kranz and associates also found that sewage workers in New York reported a significantly higher frequency of diarrhea, dizziness, headache, skin irritation, and sore throat than workers at water treatment plants.[15]

In a three–year, prospective epidemiologic study in Ohio, the health status of farming families using sludge on land was compared to families which did not.[16] The families were randomly assigned to each category. Each family participated in a monthly family and animal health questionnaire, annual tuberculin skin testing, and quarterly blood sampling for serological testing for 23 viruses.[16] There was no significant difference in the frequency of respiratory illnesses, digestive illnesses, or general symptoms between the two family groups. There were also no observed differences in health status among the farm animals. Viral serological test results were similar, and there were no tuberculin skin test conversions. According to the authors, farmers in this study had a sewage sludge application rate comparable to the practices allowed under US EPA regulations, and the sewage sludge had undergone accepted digestion procedures.

There is limited information on the presence of airborne microbial pathogens resulting from the application of sewage sludge. One study by Pillai *et al.* measured airborne bacteria during the land application process.[17] Concentrations for heterotrophic bacteria, which require nitrogen and carbon food sources, averaged 10^5 colony forming units per cubic meter (CFU/m^3). One location, where a major amount of physical agitation of the sewage sludge occurred, had detectable levels of hydrogen sulfide producing bacteria and *Clostridium spp.* (5×10^2 CFU/m^3) on three of the four days monitored at that site. Fecal coliforms, fecal streptococci, and *Salmonella sp.* were not detected at any of the sampling sites.[17]

Metals

The U.S. EPA regulations on sewage sludge land application contain maximum pollutant loading rates for specific metals.[1] These metals are arsenic (41 kilograms per hectare), cadmium (39 kilograms per hectare), chromium (3000 kilograms per hectare), copper (1500 kilograms per hectare), lead (300 kilograms per hectare), mercury (17 kilograms per hectare), nickel (420 kilograms per hectare), selenium (100 kilograms per hectare), and zinc (2800 kilograms per hectare).[18] If any of these pollutant rates are exceeded, additional sewage sludge cannot be land–applied to that site. At the LeSourdsville facility, the incoming wastewater stream and resultant effluent are also monitored for metal content to assure that high concentrations of metals are not released into the river from the final effluent.

Toluene

Toluene is a solvent found in paints and other coatings and used as a raw material in the synthesis of organic chemicals, dyes, detergents, and pharmaceuticals.[19] Toluene can enter the wastewater stream from industrial plants. Inhalation and skin absorption are the major occupational routes of entry. The main effect reported with excessive inhalation exposure to toluene is central nervous system (CNS) depression.[19] Toluene vapor can cause acute irritation of the eyes and upper respiratory tract, and liquid toluene can dry skin and cause dermatitis.[19,20]

The NIOSH REL for toluene is 100 ppm for an 8–hour TWA and 150 ppm for a 15–minute sampling period.[?] The OSHA PEL for toluene is 200 ppm for an 8–hour TWA.[?] The ACGIH TLV is 50 ppm for an 8–hour exposure level with a skin notation, indicating that cutaneous exposure contributes to the overall absorbed dose and potential systemic effects.[?]

Bacterial Endotoxin

A bacterial endotoxin is a lipopolysaccharide compound from the outer cell wall of Gram–negative bacteria, which occur abundantly in organic dusts.[21] The biological properties of endotoxin vary depending upon the bacterial species from which they are derived, as well as upon the state of the growth cycle of the bacteria.[22] Endotoxin exposure can cause fever and malaise, changes in white blood cell counts, respiratory distress, shock, and death. Endotoxin can also act as a stimulant to the immune system.[23,24]

Acute airflow obstruction from inhalation of endotoxins has been documented in some but not all of the epidemiological studies that have evaluated endotoxin;[24] acute health effects have been documented at endotoxin levels of 300 to 400 EU/m^3 and 45 to 150 EU/m^3.[25,26] Chronic health effects, including decreased pulmonary function and respiratory symptoms, have been documented in several cross–sectional epidemiological studies.[24] Some prospective epidemiological studies have found an association of endotoxin exposure with accelerated decrease of lung function. Other similar studies did not find such an association.[24] A study by Mattsby and Rylander found that approximately 40% of sewage treatment plant workers reported diarrhea, fatigue, and headache after exposure to an aerosol of sewage dust containing endotoxin.[27] Liesivouri and associates found airborne endotoxin concentrations in wastewater treatment plants to range from 8 to 410 nanograms per cubic meter (ηg/m^3) (equivalent to 80 to 4,100 EU/m^3) of air.[28] Occupational exposure criteria have not been established for bacterial endotoxin by OSHA, NIOSH, or ACGIH. Eight–hour TWA concentrations have been suggested for airway inflammation with increased airway reactivity (200 endotoxin units per cubic meter [EU/m^3]), for over–shift decline in FEV_1 (2,000 EU/m^3), for chest tightness (3,000 EU/m^3), and for toxic pneumonitis (10,000–20,000 EU/m^3).[29]

RESULTS/DISCUSSION

Microbial Air Sampling

The results of the air sampling for bacteria grown on R2Ac nutrient media are shown in Table 2. The geometric mean bacterial concentrations for the ten sets of samples collected at the concrete pad worksite ranged from 694 CFU/m^3, with a geometric standard deviation (g.s.d.) of 1.5, to 2,356 CFU/m^3 (g.s.d. of 1.3). The bacteria concentrations at the concrete pad were higher in the first set of samples which were collected while the sludge that had been stored longer was loaded unto the trucks. At the farm field worksite, the geometric mean bacterial concentrations for six sample sets ranged from

1,105 CFU/m^3 (g.s.d. of 2.2) to 2,226 CFU/m^3 (g.s.d. of 2.3). The bacteria concentrations were higher downwind of the sewage sludge pile. The geometric mean bacterial concentration at the river water release site was 412 CFU/m^3 (g.s.d. of 1.1). This site was located away from the wastewater treatment plant.

All of the bacterial genera identified from these samples are associated with outdoor environments or mammals. There were no consistently predominant genera among the samples. Among the genera identified, *Bacillus*, *Flavimonas*, *Mycobacterium*, *Pseudomonas*, *Staphylococcus*, and *Streptomyces* bacteria are found in many environments. Some species in these genera can cause disease in humans.[30,31]

Culturable bacteria were found on four sets of the incubated MacConkey agar plates. Three of these sets grew one CFU and one grew three CFU. The three single CFU plates grew *Burkholderia*, *Aeromonas*–like, and *Klebsiella*–like bacteria (identified to genus level). The multi–CFU plate grew *Burkholderia* and *Enterobacter agglomerans*. All of these are Gram–negative bacteria. Bacteria in the *Burkholderia* genus and *Enterobacter agglomerans* are opportunistic human pathogens (immunocompromised persons are more susceptible to these organisms).[30] Bacteria in the *Aeromonas* genus are commonly found in fresh water and sewage, and some are pathogenic to frogs, fish, and humans, causing diarrhea or bacteremia (infection in the bloodstream). Bacteria in the *Klebsiella* genus are found in human feces, soil, crops, and water.

Bulk Microbial Samples

For the eight bulk sewage sludge samples collected from the concrete pad, the geometric mean concentration of coliform bacteria was 2.7×10^4 CFU per gram of sample, with a g.s.d. of 5. The bulk samples were collected from different locations around the sludge pile which led to a wide variability in total bacterial counts. Actual counts for coliform bacteria ranged from 1.5×10^3 to 1.76×10^5. The geometric mean concentration of *E. coli* in the bulk samples was 2.2×10^4 CFU per gram of sample, with a g.s.d. of 3.6. The presence of *E. coli* was confirmed by the contract laboratory. The concentrations are below the US EPA allowable concentration for Class B sludge of 2×10^6 fecal coliform density (CFU) per gram of material.

Volatile Organic Compounds (VOCs)

Toluene (at low levels) was the major compound identified on the thermal desorption tubes collected around the concrete pad. Other compounds detected at trace levels included acetone, isopropanol, perchloroethylene, propylene glycol methyl ether acetate, xylene, and benzaldehyde.

Endotoxin

The results of the endotoxin air sampling are shown in Table 3. The two PBZ air sample concentrations collected on truck drivers were 20 and 24 EU/m^3. The area air endotoxin concentrations ranged from 23 to 39 EU/m^3. These levels are lower than those detected at other wastewater treatment facilities and below levels previously associated with acute health effects.[27,28,29]

Metals

The results of the metals air sampling are presented in Table 4. Low levels of aluminum, barium, iron, manganese, nickel, silver, and titanium were found (range: non–detectable to 8.6 $\mu g/m^3$). None of the other metals were detected at the LOD. All of the values detected were well below occupational exposure limits for those metals that have limits.

Observations

The total process of land–applying the biosolids during the August 1998 site visit took about 10 hours. The process time is controlled by the location of the farm and the amount of biosolids available for application. The employees working in the farm fields use a waterless hand cleaner which contains limonene, a fragrance agent, and nonylphenoxy–polyethoxyethanol, a biocidal agent. The truck drivers reported sometimes using leather gloves; the majority of time during the site visit none of the workers wore gloves. They take their work boots home to be cleaned. The employees eat lunch when they get an opportunity and wash hands whenever they can.

Medical Interviews

The five interviewed employees had worked with the biosolids land application for 5 to 10 years. All five employees reported at least one episode of gastrointestinal illness occurring after working with the biosolids (either at the treatment plant or during the land application). One worker had one episode (lasting several hours) of abdominal cramps and loose bowel movements after working in a farm field; he has had no further symptoms despite continuing the same type of work. The other four workers reported repeated, intermittent episodes of various gastrointestinal symptoms, including watery diarrhea, loose bowel movements, green–colored stool, and abdominal cramping; these workers also reported intermittent headaches. These episodes were reported to occur after working on various aspects of the land application process, including operating the front–end loader at the storage pad, driving the trucks, and applying the biosolids in the fields. The episodes have been occurring over the four years prior to filing the HHE request, although the workers reported that they seem to have been more prevalent in the several months prior to the HHE request. The symptoms were reported to last from five to ten hours; none of the workers reported symptoms consistent with chronic infection or ongoing gastrointestinal illness. Although in most cases, the symptoms resolved spontaneously, one worker reported occasionally taking a non–prescription medication to improve the symptoms. One worker was evaluated by a gastroenterologist. In that case, no specific diagnosis was made and the physician recommended minimizing exposure to sewage and sludge. Based on the employee interviews, NIOSH investigators were not able to identify specific activities related to the acute symptoms/illnesses. None of the interviewed employees reported any respiratory symptoms.

CONCLUSIONS

Employees may be exposed to sewage sludge during loading, unloading, and application activities. The detection of enteric bacteria in the air and bulk samples collected in this HHE confirms the potential for sewage workers to be occupationally exposed to organisms which have been associated with gastrointestinal symptoms/illnesses. The total bacterial concentrations detected in the air were similar to those found in the one study of airborne microorganisms from land application of sewage sludge. The detected levels of trace metals and VOCs, including toluene, were low and were well below current occupational exposure limits. Endotoxin levels were lower than those detected at other wastewater/sewage handling facilities.

While the specific component(s) of the sewage sludge responsible for the employees' symptoms have not been determined, the nature and timing of the symptoms suggest occupational exposure by inhalation or ingestion of the biosolids as a probable cause. The environmental monitoring data show that contaminated aerosols may be produced during the work process; the potential for respiratory exposures also exists (although neither respiratory symptoms nor symptoms of systemic toxicity were reported among the interviewed employees).

The sludge–handling procedures followed by LeSourdsville at the time of this HHE may be exacerbating exposures to biosolids. The practice of storing the sludge in a pile while waiting for two days for the fecal coliform count results (to determine whether the sludge is in compliance with EPA Class B requirements) is likely to result in the amplification of microorganisms. Therefore, even when sample results from the sludge piles indicate that the fecal coliform counts are at acceptable levels, there may still be 'pockets' within the sludge piles where bacterial levels remain high. This could potentially lead to intermittent exposures to high concentrations of microorganisms capable of producing gastrointestinal symptoms. Staff at the LeSourdsville facility are aware that storage of sewage sludge on the pad results in an initial increase in the concentration of fecal coliforms as the organisms use the sludge as a food source.

RECOMMENDATIONS

The following recommendations are provided to help minimize exposure to raw and processed sewage and increase employee awareness of the importance of good hygiene and the appropriate use of personal protective equipment (PPE) while at work.

1. Hand–washing stations with clean water and mild soap should be readily available wherever contact with wastewater, sewage, or sludge may occur. In the case of workers in the field, portable equipment, including clean water and soap, should be available wherever work with sewage is taking place.

2. Periodic training regarding standard hygiene practices should continue to be conducted, reviewing issues such as:

a. Frequent and routine hand washing. This is the most valuable safeguard in preventing infection by agents present in sewage.

b. Removing soiled PPE (such as gloves) after use, proper storage and disposal to avoid contaminating other objects or parts of the facility with soiled PPE, and hand washing after gloves are removed.

c. Use of available on–site showers, lockers, and laundry services for washing work clothes. Work clothes and boots should not be worn home or outside the immediate work environment.

d. Eating, drinking, or smoking should not be done while working. Employees should always wash their hands and face before engaging in these activities or using the restroom.

e. Cleaning PPE, such as protective clothing, boots, gloves, goggles, and face shields. These should be either properly cleaned (immediately after they are used) or discarded.

f. Face shields. Models that fit over employees' hard hats should be made available for all jobs in which there is a potential for spray or high–pressure sewage leaks, or when sludge is aerosolized during application.

3. Appropriate PPE should be required for all job duties likely to result in exposure to sewage, untreated or partially treated wastewater, or sludge. This PPE should include goggles, face shields, liquid–repellant coveralls, and gloves. Management and employee representatives should work together to determine which job duties are likely to result in this type of exposure and which type of PPE is needed. Adequate access to all PPE should be provided for employees on all shifts. A qualified health and safety professional should provide training or retraining in the use of appropriate PPE.

4. To reduce exposure to airborne microorganisms and endotoxin, the heavy equipment (tractors and front–end loaders) used at the concrete pad and farm fields can be retrofitted with air cleaning devices in conjunction with the air–conditioning units.[32] Adding of a particulate filtration system and maintaining the cab under positive pressure with respect to the outdoors would reduce the infiltration of outdoor contaminants. The drivers of the dump trucks could keep the windows closed and use the air–conditioning to minimize exposures.

5. The tractor cabs, front–end loaders, and truck cabs should be wiped down and vacuumed out on a regular basis to reduce potential exposure to contaminated material.

6. Sludge should not be stored prior to land application. The sewage treatment process should result in production of sewage sludge (decontamination of the sewage) which meets EPA Class B requirements as it is produced. Improved laboratory turn–around time to document the level of

fecal coliforms as the sludge is produced should be instituted so that the sewage sludge is land–applied shortly thereafter without storage. Continued consultation with experts in land application of sludge (for example, staff from the Ohio State University) may be useful in achieving this goal.

7. Since employees are at risk of soil–contaminated injuries, management should insure that all employees are up–to–date on tetanus–diphtheria immunizations.

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Table 1
Examples of Pathogens Potentially Found in Wastewater and Sewage Sludge[2]
LeSourdsville Bio--Solids Land Application Process
LeSourdsville, Ohio
HETA 98–0118

Organism	Disease or Symptoms
Bacteria	
Campylobacter jejuni	Gastroenteritis
Escherichia coli	Gastroenteritis
Salmonella sp.	Salmonellosis (food poisoning), typhoid fever
Shigella sp.	Bacillary dysentery
Vibrio cholerae	Cholera
Yersinia sp.	Acute gastroenteritis (including diarrhea, abdominal pain)
Enteric Viruses	
Astroviruses	Epidemic gastroenteritis
Caliciviruses	Epidemic gastroenteritis
Enteroviruses–Coxsackieviruses	Meningitis, fever, hepatitis, pneumonia, etc.
Enteroviruses–Echoviruses	Meningitis, diarrhea, fever, paralysis, etc.
Enteroviruses–Polioviruses	Poliomyelitis
Hepatitis A virus	Infectious hepatitis
Norwalk viruses	Epidemic gastroenteritis with severe diarrhea
Reovirus	Respiratory infections, gastroenteritis

Table 1
Examples of Pathogens Potentially Found in Wastewater and Sewage Sludge[2] (continued)
LeSourdsville Bio–Solids Land Application Process
LeSourdsville, Ohio
HETA 98–0118

Organism	Disease or Symptoms
Protozoa	
Balantidium coli	Diarrhea and dysentery
Cryptosporidium	Gastroenteritis
Entamoeba histolytica	Acute enteritis
Giardia lamblia	Giardiasis (including diarrhea, abdominal cramps, weight loss)
Toxiplasma gondii	Toxoplasmosis
Helminth Worms	
Ascaris lumbricoides	Abdominal pain, digestive and nutritional disturbances, restlessness, vomiting,
Ascaris suum	May produce symptoms such as chest pain, coughing, and fever
Hymenolepsis nana	Taeniasis
Necator americanus	Hookworm disease
Taenia saginata	Abdominal pain, anorexia, digestive disturbances, insomnia, nervousness
Taenia solium	Abdominal pain, anorexia, digestive disturbances, insomnia, nervousness
Toxocara canis	Abdominal discomfort, fever, muscle aches, neurological symptoms
Trichuris trichiura	Abdominal pain, anemia, diarrhea, weight loss

Table 2
Culturable Bacteria Air Sampling Results
LeSourdsville Bio–Solids Land Application Process LeSourdsville, Ohio HETA 98–0118

Sample Location	Bacteria Concentrations Geometric Mean (CFU/m^3)*	Geometric Standard Deviation	Taxonomic Rank	Number of Sample Sets
Inside Concrete Pad	1884	1.0	*Pseudomonas*, not *aeruginosa* (35%), *Staphylococcus*, not *aureus* (18%), *Streptomyces*–like (15%), *Micrococcus luteus* (4%) *Bacillus* (5%), Gram positive rod (2.5%)	2
Next to Dump Truck	1730	2.4	*Mycobacterium*–like (65%), *Acinetobacter* (13%),*Staphylococcus*, not *aureus* (5%), Gram positive rod (5%) *Streptomyces*–like (5%)	2
Upwind of Concrete Pad	2356	1.3	*Mycobacterium*–like (77%), *Corynebacterium*–like (9%), *Bacillus* (3%), *Acinetobacter*–like (2%)	2
Field – Downwind of Pile	2226	2.3	*Acinetobacter* (61%), *Arthrobacter*–like (12%), Gram positive rod (9%), *Brevibacterium*–like (9%), *Curtobacterium*–like (4%)	2
Side Wind – Next Field	1478	1.0	*Acinetobacter*–like (26%), Gram positive rod (16%), *Curtobacterium*–like (11%), *Streptomyces*–like (8%), *Flavobacterium* (6%), *Bacillus* (5%), *Corynebacterium*–like (1%), Methylbacterium (1%)	2
Field Loading Site	1105	2.2	*Flavobacterium* –like (24%), *Curtobacterium*–like (18%), *Agrobacterium*–like (10%), *Flavobacterium* (7%), *Bacillus* (2%)	2
Inside Concrete Pad II	694	1.5	*Bacillus* (25%), *Curtobacterium*–like (20%), *Streptomyces*–like (16%), *Acinetobacter* (8%), *Flavobacterium*–like (3%)	4
Upwind by River Release	412	1.1	*Bacillus* (27%), Gram negative rod (19%), *Flavimonas* (13%), *Acinetobacter* (11%), *Flavobacterium* (9%), *Flavobacterium*–like (4%)	2

*** CFU/m^3 = colony forming units per cubic meter**

Table 3
Endotoxin Air Sampling Results
LeSourdsville Bio–Solids Land Application Process
LeSourdsville, Ohio
HETA 98–0118

Sample Location	Sampling Time	Sample Volume (Liters)	Concentration (EU/m^3)*
Personal			
Truck Driver	9:28 a.m. – 3:09 p.m.	512	19.7
Truck Driver	9:08 a.m. – 2:05 p.m.	446	24
Area			
Cab of Front–end Loader at Farm	10:51 a.m. – 3:06 p.m.	383	39
Cab of Spreader at Farm	10:58 a.m. – 3:14 p.m.	384	23.7
Center Post at Concrete Pad	8:58 a.m.– 2:39 p.m.	512	23
Minimum Detectable Concentration (MDC)		383	1.3

* EU/m^3 = endotoxin units per cubic meter

Table 4
Metals Air Sampling Results
LeSourdsville Bio–Solids Land Application Process
LeSourdsville, Ohio HETA 98–0118

Sample Location	Sampling Time	Sample Volume (liters)	Concentration ($\mu g/m^3$)*						
			Aluminum	Barium	Iron	Manganese	Nickel	Silver	Titanium
Concrete Pad – Center Post	8:59 a.m. – 2:39 p.m.	680	ND**	Trace^	ND	0.3	ND	ND	ND
Concrete Pad– Back Post	9:04 a.m. – 2:42 p.m.	676	ND	Trace	ND	Trace	ND	ND	0.8
Cab of Field Front–End Loader	10:51 a.m. – 3:06 p.m.	510	8.6	Trace	Trace	0.3	ND	Trace	Trace
Cab of Spreader Tractor	10:58 a.m.– 3:14 p.m.	512	ND	ND	ND	0.4	Trace	ND	ND
MDC^^		510	1.96	0.1	1.57	0.02	0.98	0.16	0.39
MQC#		510	7.84	0.39	5.88	0.08	1.96	0.59	0.78
OSHA PELs			15000	NA##	10000 (iron oxide)	1000	1000	100	15000 (TiO_2)++
NIOSH RELs			10000	NA	5000 (iron oxide)	500 (ceiling)	15 (Ca)+	100	CA (TiO_2)
ACGIH TLVs			10000	500	5000 (iron oxide)	200	1500	100	10000 (TiO_2)

* = micrograms per cubic meter ($\mu g/m^3$)
** = not detected (ND)
^ = Trace (between MDC and MQC)
= not applicable(NA)
\+ = carcinogen (CA)
++ = titanium dioxide (TiO_2)
^^ = minimum detectable concentration (MDC)
# = minimal quantifiable concentration (MQC)

National Institute for Occupational Safety and Health (NIOSH) Study Looking at Working With Biosolids

In 1998, NIOSH conducted a health hazard evaluation at the Butler County Department of Environmental Services, LeSourdsville, Ohio, facility to look at exposures from the land-application of sewage sludge (biosolids). Workers reported headaches, stomach cramps, and diarrhea.

What NIOSH Did

We collected air samples for bacteria, endotoxin (chemical in some bacteria), metals, organic chemicals, and bulk sewage sludge samples for fecal coliform bacteria.

We talked to all the employees who worked in the biosolids land application process about their health and work practices.

What NIOSH Found

Bacteria that can sometimes cause illnesses were found in air and sludge samples.

Employee exposures to metals and chemicals were very low.

Employee symptoms were likely caused by inhalation or ingestion of the biosolids.

What Bio–Solids Land Application Process Managers Can Do

Continue to provide training on personal hygiene practices.

Apply sewage sludge as soon as possible after processing.

Reduce laboratory turn–around time for fecal coliform results.

Provide additional portable hand-washing stations at fields.

Provide and train workers on type, use, and disposal of personal protective equipment (PPE).

Add air filtration systems to heavy equipment.

Clean inside of heavy equipment on a regular basis.

What the Bio–Solids Land Application Process Employees Can Do

Wash hands frequently especially before eating, drinking, or smoking and after removing gloves.

Use PPE when needed.

Close windows and use air–conditioning in heavy equipment cabs.

Use work showers and uniforms and leave boots at work.

CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION

What To Do For More Information:
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513/841-4252 and ask for HETA Report # 98-0118-2748

National Institute for Occupational Safety and Health
NIOSH

HHE Supplement

For Information on Other
Occupational Safety and Health Concerns

Call NIOSH at:
1–800–35–NIOSH (356–4674)
or visit the NIOSH Web site at:
www.cdc.gov/niosh

National Institute for Occupational Safety and Health
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