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Rumpke, Inc. Landfill
Colerain Township, Ohio

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PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Daniel Almaguer, M.S., and Ken Martinez, M.S.E.E., C.I.H., of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Dave Sundin, Dave Marlow, Dino Mattorano, Greg Kinnes, and Angela Weber. Desktop publishing by Kate L. Marlow.

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Health Hazard Evaluation Report HETA 96-0109-2616
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Colerain Township, Ohio
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SUMMARY

On March 18, 1996, the National Institute for Occupational Safety and Health (NIOSH) received a request to assist the Hamilton County General Health District with the assessment of airborne microbiologic aerosols at the Rumpke Incorporated, landfill in Colerain Township, Ohio. On March 9, 1996, the north slope of "Mount Rumpke" slid into an adjacent area excavated by the Rumpke Mountain Mining Operations exposing 20 to 30 acres of garbage at the site. During the week of March 18, 1996, a mixture of blended cellulose and synthetic fibers was sprayed over the exposed garbage to provide a cover layer. An odor control agent was also sprayed near the exposed garbage to reduce or eliminate odors.

On the afternoon of March 18, 1996, NIOSH investigators conducted an initial walk-through inspection of the Colerain Township landfill and returned on April 3, and 11, 1996, to assess general area air concentrations of airborne particulates, hydrogen sulfide (H_2S), volatile organic compounds (VOCs), and bioaerosols. Area air samples were collected at six locations; three on-site and three off-site around the perimeter.

The airborne concentrations measured on the survey days did not exceed the NIOSH recommended exposure limits (RELs), the Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs), or American Conference of Governmental Industrial Hygienists (ACGIH®) threshold limit values (TLVs®). The highest detectable concentrations for all substances (including bioaerosols) were found inside the landfill compactor cab. Samples for respirable particulates did not contain quartz, but the existence of quartz in the side by side samples for total particulates collected inside the compactor cab cannot preclude the possibility of respirable quartz. Real-time particulate measurement results also indicate that airborne particulate, less than 10 µm in diameter, at all sampling locations was below 0.150 milligrams per cubic meter. Results of H_2S sampling showed trace concentrations of H_2S present at most locations, and trace concentrations of other sulfur compounds were present in the landfill compactor cab on the second day of sampling.

Bioaerosol samples were collected to determine area concentrations of culturable microorganisms (i.e., fungi, total bacteria, and enteric bacteria), fungal spores, and endotoxins. The results of the air samples for culturable enteric bacteria are indicative of possible microbiologic dissemination from the working face of the landfill to perimeter areas (created by disruptive activities, such as movement of the large compactors). While the results of the air samples for fungal spore counts revealed no uniquely distinguishing findings, the concentrations detected in the cab of the compactor were consistently higher than all other sample concentrations. This is likely the direct result of the disruptive activity of the compactor on the landfill contents (and the fungal reservoirs present within).

Finally, the results of the air sampling for endotoxins (in the compactor cab) were marginally above those from all other sample locations.

All sampled airborne contaminants were well below the occupational exposure criteria. The isolation of enteric bacterial species around the periphery of the landfill supports the conclusion of possible microbiologic dissemination from the working face. The concentrations observed at the Rumpke landfill are consistent with bioaerosol studies of municipal landfills reported in the literature. The absence of definitive exposure criteria precludes the ability to assess the risks of such bioaerosol exposures. However, these results do indicate that the highest concentrations of particulates (including spore counts) measured were inside the landfill compactor cab. A review of the literature indicates that exposures to total dust and respirable quartz in excess of the occupational exposure criteria have been associated with landfilling operations. To protect the landfill compactor operators from exposures to respirable quartz and various genera of microorganisms, the retrofitting of landfill compactors with particulate air filters is warranted.

Keywords: SIC 4953 (Refuse Systems) landfills, hydrogen sulfide, volatile organic chemicals, total hydrocarbons, total particulate, quartz, bioaerosols, endotoxins, fungi, bacteria.

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INTRODUCTION

On March 18, 1996, the National Institute for Occupational Safety and Health (NIOSH) received a request to assist the Hamilton County General Health District with assessment of airborne microbiologic aerosols associated with a slope failure at the Rumpke Incorporated, landfill in Colerain Township, Ohio. This report presents the results and conclusions regarding the NIOSH environmental evaluations conducted on April 3 and 11, 1996.

BACKGROUND

On March 9, 1996, the north slope of "Mount Rumpke" slid into an adjacent area excavated by the Rumpke Mountain Mining Operations exposing 20 to 30 acres of garbage at the site. During the week of March 18, 1996, a mixture of blended cellulose and synthetic fibers was sprayed over the exposed garbage to provide a cover layer. An odor control agent was also aerosolized at various points near the exposed garbage in an attempt to reduce or eliminate odors. Currently, about 120 acres are used to landfill municipal waste and Rumpke, Inc. is permitted to landfill approximately 235 acres at the Colerain Township site.

The Hamilton County General Health District and an industrial hygiene consultant for Rumpke, Inc. conducted sampling for methane gas, particulates, and asbestos in and around the landfill site following the slope failure. On the afternoon of March 18, 1996, NIOSH investigators conducted an initial walk-through inspection at the landfill site, and were accompanied by the Director of Water Quality and Waste Management and the Waste Management Manager for the Hamilton County General Health District, as well as representatives of the Rumpke Department of Engineering and Environmental Affairs.

Based on the March 18th walk-through inspection, it was determined that general area air sampling should be conducted on-site, inside the landfill area, and along the perimeter of the site to determine general area air concentrations of airborne particulates, volatile organic compounds (VOCs), and bioaerosols. However, because of the unpredictable spring weather, air sampling was postponed until April 3 and 11, 1996. Area air samples were collected at six locations; three off-site around the perimeter of the landfill and three on-site. The three perimeter sites were the same locations used during the previous sampling conducted by the Health Department, based on the expected wind direction (the wind direction varied at times on the second day of sampling). Perimeter locations chosen were upwind (off Old Colerain Avenue), downwind (at the Director's home), and sidewind (off Bank Road). The on-site sampling locations chosen were the barn where the odor control agent was being sprayed, at the working face of the landfill, and inside a landfill compactor cab (bioaerosol samples not collected inside the cab).

METHODS

Industrial Hygiene Sampling

Samples collected at the off-site perimeter locations and at the barn (on-site) included a sample to conduct a qualitative screening for volatile organic compounds (VOCs) that may have been emitted from the decomposing garbage, a sample to quantitate selected VOCs identified on the qualitative samples, and a sample for hydrogen sulfide (H_2S). Perimeter samples were collected to evaluate the potential dissemination of contaminants from the landfill. Quantitation would have required much higher flowrates and longer sample times than those used during this evaluation. Samples for all previously mentioned substances were collected at the working face of the landfill and inside the compactor cab, as well as other sulfur compounds, and total and respirable particulate.

Total and respirable particulate

Total dust samples were obtained using battery-powered pumps calibrated at a flowrate of 2.0 liters per minute (ℓpm) attached via Tygon® tubing to pre-weighed (tared) 37 millimeter (mm) diameter polyvinyl chloride (PVC) filters with a 5 micrometer (µm) pore size. Respirable particulate samples were also collected on tared PVC filters using battery-powered pumps calibrated at a flowrate of 1.7 ℓpm connected via Tygon® tubing to a Dorr-Oliver nylon cyclone particle size selector which removes particulates exceeding an aerodynamic diameter of 10 µm. Gravimetric analyses were performed for total and respirable particulates using NIOSH methods 0500 and 0600, respectively.[1] The analytical sensitivity was 0.01 milligrams (mg) per sample. Samples were further analyzed for quartz and cristobalite using x-ray diffraction in accordance with NIOSH Method 7500.[1]

Hydrogen sulfide and sulfur compounds

General area air samples for H_2S were collected on Orbo™ 32 solid sorbent tubes (400/200 charcoal) according to NIOSH Method 6013.[1] Area samples for other sulfur compounds were collected on Orbo™ 43 solid sorbent tubes and analyzed by gas chromatography (GC) with Sulfur Chemiluminescence Detection (SCLD).

Qualitative samples for VOCs

Qualitative samples for VOCs were collected on thermal desorption tubes connected via Tygon® tubing to battery-powered sampling pumps calibrated to provide a volumetric airflow rate of 0.02 ℓpm. Samples for VOCs were screened via gas chromatography/mass spectrometry (GC/MS).

Quantitative samples for VOCs

Quantitative samples for VOCs were collected on 100/50 milligram solid sorbent charcoal tubes connected via Tygon® tubing to battery-powered sampling pumps calibrated to provide a volumetric airflow rate of 0.2 ℓpm. Significant analyte peaks identified on the qualitative screening samples were analyzed by GC with flame ionization detection (FID) in accordance with NIOSH Methods 1501 and 1550[1].

Temperature and relative humidity

On April 3, 1996, temperature and relative humidity were measured using a Vaisala Model HM 34 battery-powered, direct reading meter. This instrument is capable of providing direct readings for dry-bulb temperature and relative humidity (RH), ranging from -4°F to 140°F and 0% to 100%, respectively. Instrument calibrations are performed monthly using primary standards. Readings obtained with this meter appeared to be higher than the actual temperature and RH on the day of the survey. Therefore, on April 11, 1996, temperature and RH measurements were obtained using a Psychro-Dyne® psychrometer. This instrument utilizes the wet and dry bulb method of measuring moisture in the air, which is based on the cooling effect of the wet bulb.

Bulk material samples

Bulk material samples of the odor control agent were collected in 20 mL glass vials and submitted to the laboratory for analysis via GC/MS.

Microbiologic Aerosol Sampling

To determine general area air concentrations of culturable airborne fungi, total bacteria, and enteric bacteria, the Spiral Air Systems (SAS) Portable High Flow Model 5203 (Pool Bioanalysis Italiana, Milano, Italy) was used at a calibrated flowrate of 186 ℓpm over sample periods of 1 to 2 minutes. Sampling times were adjusted based on the estimated loading at a particular sampling location (e.g., 1 minute sample times were used at the working face based on higher expected bioaerosols concentrations). Malt Extract agar was used for the enumeration of total fungi, tryptic soy agar was used for the enumeration of total bacteria, and

MacConkey's agar was used for the enumeration of enteric bacteria. Sample plates were incubated at 30˚C. The taxa and rank of the collected microorganisms were determined by morphological characteristics and/or biochemical tests.

Bioaerosol air samples were collected at two locations inside the landfill property line and three locations around the perimeter. At each sample location, at least three replicate samples per sampling day were collected for culturable fungi, total bacteria, and enteric bacteria. Four replicates per sampling day were collected at the working face and odor control locations. The number of replicates was increased to improve the statistical confidence of the on-site areas for comparison to peripheral zones. Sampling at each location was conducted on two separate days (approximately 2 hours per sampling location). Temperature and RH were recorded for each location.

To determine general area concentrations of airborne fungi and Gram-negative bacteria using non-culturable sampling methods, air was drawn through filters, via flexible Tygon® tubing, with Gilian® Model HFS 513A high flow personal sampling pumps. Airborne fungal spores were collected on a 37-millimeter (mm) mixed cellulose ester (MCE) filter at a calibrated flow rate of 2 ℓpm with subsequent optical microscopic analysis. Each filter sample was analyzed according to a modification of NIOSH Method 7400.[1] One quarter of each filter sample was cleared with acetone vapor and mounted in a phloxine-alcohol-glycerin mounting medium. (Phloxine is a biological dye that stains fungal spores pink.) The prepared slide was allowed to sit over night or was heated gently to enhance staining before reading. Slide samples were scanned (200 fields per sample) at 400x magnification using bright field or phased contrast illumination. Only particles greater that 2 µm in diameter were considered as possible fungal spores.

Samples for endotoxin (a cell wall constituent of Gram-negative bacteria) were collected on a 37-mm polyvinyl chloride (PVC) filter at a calibrated flow rate of 2 liters per minute (ℓpm). Each filter sample was analyzed gravimetrically (NIOSH Method 0500[1]) and subsequently placed into 50 ml conical centrifuge tubes. Ten milliliters of sterile, pyrogen-free water (LAL Reagent Water, BioWhittaker Inc., Walkerville, Maryland) was added to each tube. The filter samples were gently rocked at room temperature for approximately 60 minutes. Each supernate was then decanted in a 15 ml centrifuge tube and centrifuged for 10 min at 2200 revolutions per minute (rpm) at 4˚C. From each tube, 3 ml of the supernatant fluid was recovered, placed in a sterile vial, and stored at -85˚C until analyzed. The samples were assayed for endotoxin content using the Kinetic-QCL Assay Kit (BioWhittaker, Walkerville, MD) according to the manufacturer's recommended procedure.

Real-time Particulate Measurement

Real-time sampling for airborne particulates was conducted with the Grimm Model 1105 Dust Monitor (Labortechnik GmbH & CoKG, Ainring, Germany). The Grimm Dust Monitor is a light scattering aerosol spectrometer designed for real-time particulate measurement with particle size discrimination. Eight channels collect count information for particle sizes of greater than 0.75, 1, 2, 3.5, 5, 7.5, 10, and 15 µm. Data was collected simultaneously with the culturable microbiologic aerosols (over an approximate 2 hour period) at the same five sampling locations. For each sampling location, data was integrated for 1 minute and stored sequentially on the Grimm data card over the entire sampling period. The collected particle count and size information was downloaded to a laptop computer following the completion of the sampling day.

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 increase 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)[2], (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs)[3] and (3) the U.S. Department of Labor, OSHA Permissible Exposure Limits (PELs)[4]. In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this report reflect the 1971 values.

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 short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Particulates, Not Otherwise Classified

Often the chemical composition of the airborne particulate does not have an established occupational health exposure criterion. It has been the convention to apply a generic exposure criterion in such cases. Formerly referred to as nuisance dust, the preferred terminology for the non-specific particulate ACGIH TLV criterion is now *"particulates, not otherwise classified (n.o.c.),"* [or *"not otherwise regulated"* (n.o.r.) for the OSHA PEL]. In comments to OSHA on August 1, 1988, on their "Proposed Rule on Air Contaminants," NIOSH questioned whether the proposed PEL for PNOR (10 mg/m^3) was adequate to protect workers from recognized health hazards.

The OSHA PEL for total particulate, n.o.r., is 15.0 mg/m^3 and 5.0 mg/m^3 for the respirable fraction, determined as 8-hour averages. The ACGIH recommended TLV for exposure to a particulate, n.o.c., is 10.0 mg/m^3 (total dust, 8-hour TWA). These are generic criteria for airborne dusts which do not produce significant organic disease or toxic effect when exposures are kept under reasonable control.[5] These criteria are not appropriate for dusts that have a biologic effect.

Silica (Amorphous, Quartz, Cristobalite)

Amorphous silica does not have a crystalline lattice molecular configuration. Historical evaluations of amorphous silica suggest that it is of low toxicity, and it has not been reported to produce fibrotic nodules in lung tissue (characteristic of crystalline silica exposure).[6,7] The NIOSH REL for exposure to amorphous silica is a full-shift, total particulate TWA of 6 mg/m^3, providing the silica contains less than 1% crystalline forms.[8] The OSHA PEL is 80 mg/m^3 divided by the %SiO_2, as an 8-hour TWA. The ACGIH TLV for amorphous silica containing less than 1% crystalline silica is 10 mg/m^3, inhalable particulate TWA over eight hours, and a respirable particulate TWA of 3 mg/m^3.

Crystalline silica (quartz) and cristobalite have been associated with silicosis, a fibrotic disease of the lung caused by the deposition of fine particles of crystalline silica in the lungs. Symptoms usually develop insidiously, with cough, shortness of breath, chest pain, weakness, wheezing, and non-specific chest illnesses. Silicosis usually occurs after years of exposure, but may appear in a shorter period of time if exposure concentrations are very high. The NIOSH RELs for respirable quartz and cristobalite are 50 $\mu g/m^3$, as TWAs, for up to 10 hours per day during a 40-hour work week.[2] These RELs are intended to prevent silicosis. However, evidence indicates that crystalline silica is a potential occupational carcinogen and NIOSH is currently reviewing the data on carcinogenicity.[9,10,11,12] The OSHA PELs for respirable quartz is 10 mg/m^3 divided by the value "%SiO_2+2," the PEL for cristobalite is ½ the calculated value for quartz.[8] The ACGIH TLVs for respirable quartz and cristobalite are 100 and 50 $\mu g/m^3$, as 8-hour TWAs, respectively.

Hydrogen Sulfide

Hydrogen sulfide (H_2S) is a colorless, flammable gas with a strong odor of rotten eggs. In landfills, the majority of the H_2S is present as a result of decaying organic matter. Acute exposure to H_2S at airborne concentrations above 10 parts per million (ppm) has been associated with the development of conjunctivitis and keratitis.[13] One hour exposure to H_2S concentrations between 50 and 100 ppm can produce mild eye and respiratory irritation which becomes markedly worse when the concentrations are in the 200 to 300 ppm range. At H_2S concentrations between 500 and 700 ppm, exposures for 0.5- to 1-hour can result in unconsciousness and death, and between 1000 to 2000 ppm or more, unconsciousness and death can occur within minutes. Conclusive evidence of adverse health effects from chronic exposure to hydrogen sulfide at concentrations below 20 ppm is lacking.[13,14,15,16] However, there is some evidence that H_2S alone at low concentrations, or in combination with other chemical substances (e.g. petroleum products or carbon disulfide), is associated with the development of nervous system, cardiovascular, and gastrointestinal disorders, and effects on the eyes. Repeated exposure to H_2S results in increased susceptibility, so that eye irritation, cough, and systemic effects may result from concentrations previously tolerated without effect. Hydrogen sulfide has an odor threshold between 0.002 and 0.003 ppm for humans.[15] The smell is faint but easily perceptible at 0.77 ppm and offensive at 3 to 5 ppm. Up to about 30 ppm, H_2S smells of rotten eggs, but at about 30 ppm the smell is described as sweet or sickening sweet. At 150 ppm, H_2S causes olfactory-nerve paralysis and the smell is no longer perceptible. The smell of H_2S therefore is not a reliable warning of its presence, especially at high concentrations.

In a recent study, Bhambhani, et al.[17] compared the effects of inhalation of 5 ppm H_2S on the physiological and hematological responses of healthy men and women during exercise. Subjects included in the study completed two 30-minute exercise tests on a cycle ergometer at 50% of their predetermined maximal aerobic power while breathing medical air or 5 ppm H_2S from a specially designed flow system. The results indicated that there were no significant differences between the two exposures for the metabolic (oxygen uptake, carbon dioxide production, respiratory exchange ratio), cardiovascular (heart rate, blood pressure, rate pressure production), arterial blood (oxygen and carbon dioxide tensions, pH), and perceptual (rating of perceived exertion) responses in either sex. None of the subjects reported any adverse health effects subsequent to the H_2S exposure. These results suggest that healthy men and women can safely perform moderate intensity work in environments contaminated with 5 ppm H_2S or lower. The device used to deliver H_2S to the subjects fits in their mouths and did not result in exposure to the subjects' eyes. This is important since adverse effects on the eyes are what the NIOSH and OSHA exposure limits are based on.

The NIOSH REL for H_2S is a 10-minute ceiling concentration of 10 ppm.[2] When there is a potential for exposure to H_2S at a concentration of 50 ppm or higher, continuous monitoring is recommended by NIOSH. The OSHA standard for H_2S is a 10-minute ceiling concentration of 20 ppm or a maximum allowable peak of 50 ppm for 10-minutes once, if no other measurable exposures occur.[4] The ACGIH recommends a TLV-TWA of 10 ppm and a STEL of 15 ppm.[3]

Microorganisms

Microorganisms (including fungi and bacteria) are normal inhabitants of the environment. The saprophytic varieties (those utilizing non-living organic matter as a food source) inhabit soil, vegetation, water, or any reservoir that can provide an adequate supply of a nutrient substrate. Under the appropriate conditions (optimum temperature, pH, and with sufficient moisture and available nutrients) saprophytic microorganism populations can be amplified. Through various mechanisms, these organisms can then be disseminated as individual cells or in association with soil or dust particles or water droplets. In the outdoor environment, the levels of microbial aerosols will vary according to the geographic location, climatic conditions, and surrounding activity.

Some individuals manifest increased immunologic responses to antigenic agents encountered in the environment. These responses and the subsequent expression of allergic disease is based, partly, on a genetic predisposition.[18] Allergic diseases typically associated with exposures in indoor environments include allergic rhinitis (nasal allergy), allergic asthma, allergic bronchopulmonary aspergillosis (ABPA), and extrinsic allergic alveolitis (hypersensitivity pneumonitis).[19] Allergic respiratory diseases resulting from exposures to microbial agents have been documented in agricultural, biotechnology, office, and home environments.[20,21,22,23,24,25,26,27]

Symptoms vary with the type of allergic disease: (1) allergic rhinitis is characterized by paroxysms of sneezing; itching of the nose, eyes, palate, or pharynx; nasal stuffiness with partial or total airflow obstruction; rhinorrhea with postnasal drainage; (2) allergic asthma is characterized by episodic or prolonged wheezing and shortness of breath due to bronchial narrowing; (3) ABPA is characterized by the production of IgE and IgG antibodies with symptoms of cough, lassitude, low grade fever, wheezing, and occasional expectoration of mucous.[19,28] Heavy exposures to airborne microorganisms can result in an acute form of extrinsic allergic alveolitis which is characterized by chills, fever, malaise, cough, and dyspnea (shortness of breath) appearing 4 to 8 hours after exposure. Onset of the chronic form of extrinsic allergic alveolitis is thought to be induced by a continuous low-level exposure, and onset occurs without chills, fever, or malaise but is characterized by progressive shortness of breath with weight loss.[29]

Acceptable levels of airborne microorganisms have not been established, primarily due to the varying immunogenic susceptibilities of individuals. Relationships between health effects and environmental microorganisms must be determined through the combined contributions of medical, epidemiologic, and environmental evaluation.[30] The current strategy for on-site evaluation involves a comprehensive inspection of problem areas to identify sources of microbial contamination and routes of dissemination. In limited situations, air samples for microorganisms may be collected to document the airborne presence of a suspected microbial contaminant. Airborne dissemination (characterized by elevated levels compared to reference background locations and an anomalous ranking among the microbial species) correlated to symptomology may suggest that the contaminant may be responsible for the health effects.

Endotoxins

A bacterial endotoxin is a lipopolysaccharide (LPS) compound from the outer cell wall of gram negative bacteria, which occur abundantly in organic dusts.[31] It has been suggested that the lipid portion of the LPS is responsible for the molecule's characteristic toxicity.[32] 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.[33] Endotoxins have a wide range of biological activities involving inflammatory, hemodynamic, and immunological responses. Of most importance to occupational exposures are the activities of endotoxin in the lung.[34] The primary target cell for endotoxin-induced damage by inhalation is the pulmonary macrophage. Human macrophages in particular have been shown to be extremely sensitive to the effects of endotoxin in vitro.[35] Endotoxin, either soluble or associated with particulate matter, will activate the macrophage, causing the cell to produce a host of mediators.[34]

Clinically, little is known about the response to inhaled endotoxins. Exposure of previously unexposed persons to airborne endotoxin can result in acute fever, dyspnea, coughing, and small reductions in forced expiratory volume in one second (FEV1), although some investigators have not been able to demonstrate acute changes in FEV1.[34] The effects of repeated exposure to aerosols of endotoxins in humans are not known. Some animal studies have demonstrated a chronic inflammatory response characterized by goblet cell hyperplasia and increased mucous production. This suggests that repeated exposure may cause a syndrome similar, if not identical, to chronic bronchitis.[34]

Occupational exposure criteria have not been established for bacterial endotoxin by either OSHA, NIOSH, or ACGIH. However, Rylander has reported that a sufficient toxicological data base is believed to exist for establishing an occupational limit for endotoxin based on acute changes in pulmonary function.[36] Eight-hour TWA concentrations have been suggested for airway inflammation with increased airway reactivity [200 endotoxin units per cubic meter (EU/m^3)], over-shift decline in FEV1 (2000 EU/m^3), for chest tightness (3000 EU/m^3), and toxic pneumonitis (10,000-20,000 EU/m^3).

RESULTS

Industrial Hygiene

The results of sampling for total and respirable particulates are presented in Table 1. The airborne concentrations measured on the survey days did not exceed the OSHA PELs or ACGIH TLVs. The total particulate samples collected in the landfill compactor cab showed detectable quantities of quartz, however, the corresponding side by side samples for respirable particulate did not contain quartz. The results of real-time sampling for airborne particulates are also presented in Table 1. These results indicate that airborne concentrations of particulates less than 10 μm at all sampling locations were below 0.150 milligrams per cubic meter.

Samples for H_2S and other sulfur compounds are presented in Table 2. These results indicate that trace concentrations of H_2S were present at most locations, and a trace concentration of other sulfur compounds was present in the landfill compactor cab on the second day of sampling.

Qualitative VOC samples showed that samples collected in the landfill compactor cab had greater concentrations of contaminants than other locations. The primary compounds detected via GC/MS included C_3-C_6 alkanes, toluene, xylenes, styrene, limonene, acetone, isopropanol, and various C_9-C_{15} aliphatics. Other minor compounds detected included methylene chloride, methyl ethyl ketone, tetrahydrofuran, butyl acetate, perchloroethylene, 1,1,1-trichloroethane, and siloxanes.

Quantitative sample results for VOCs are presented in Table 2. These samples were analyzed for total hydrocarbons and quantitation was performed using standards spiked from a bulk Stoddard solvent. The term volatile organic compounds refers to a large class of organic chemicals (i.e., containing carbon) that have sufficiently high vapor pressure to allow some of the compounds to exist in the gaseous state at room temperature. Total hydrocarbons are organic chemicals consisting exclusively of the elements carbon and hydrogen, derived principally from petroleum, coal tar, and plant sources.[37]

During the first day of sampling, trace concentrations of total hydrocarbons were detected at the Bank Road location and a concentration of 3.73 mg/m^3 was detected inside the landfill compactor cab. On the second day of sampling a concentration of 1.4 mg/m^3 was detected inside the landfill compactor cab. Detectable airborne concentrations of total hydrocarbons were not found at any other sample location the two days of sampling. The concentrations detected were approximately 1% or less of the occupational exposure criteria for Stoddard solvent. Because these samples were quantitated using a Stoddard solvent standard the occupational criteria for Stoddard solvent is used for comparison purposes. Stoddard solvent is a mixture of predominantly C_9 - C_{11} hydrocarbons, of which 30% to 50% are straight- and branched-chain paraffins, 30% to 40% naphthenes, and 10% to 20% aromatic hydrocarbons, and is chemically similiar to mineral spirits.[6] The NIOSH REL for Stoddard solvent is 350 mg/m^3 as an 8-10 hour TWA concentration, the OSHA standard is an 8-hour TWA concentration of 525 mg/m^3, and the ACGIH TLV-TWA is 525 mg/m^3.

Analysis of the bulk material sample of the odor control spray showed that the major components of the liquid were a variety of terpene/terpene derivatives, isopropanol, diethanolamine, and triethanolamine.

Microbiologic Aerosols

Summary results of the air samples for culturable enteric bacteria are presented in Table 3 and Figure 1. (Note, a predominant number of the sample plates for culturable fungi and total bacteria were over-grown to the point of being too numerous to count. As a consequence, the data from these samples are not reported.) Variations at each sampling location between the two days of sampling are observable. However, consideration of the prevailing wind direction at the time of sampling provides consistent trends between sampling locations and the enteric microbiologic concentrations and predominant species. These trends are indicative of possible microbiologic dissemination from the working face of the landfill to perimeter areas (created by disruptive activities, such as movement of the large compactors).

Samples collected at the working face upwind on the first day of sampling resulted in no colony forming units (CFU) on the sample plates. Samples collected on the second day (the same location but downwind of the working face) resulted in an arithmetic mean concentration of 21 CFU per cubic meter of air (CFU/m^3) of culturable airborne enteric bacteria. The samples were predominated by *Rhanella aquatilis*, *Pantoea agglomerans*, and yeasts, with lesser numbers of *Enterobacter agglomerans*, variants of *Pseudomonas fluorescens*, *Acinetobacter genospecies*, and *Agrobacterium rhizogenes*. Samples collected in the proximity of the odor control system (downstream at the time of sampling for both days) resulted in arithmetic mean concentrations of 11 and 10 CFU/m^3. The taxonomy of the samples were consistent with that of the working face samples, although the ranking was slightly different. Samples collected at a residence on Hughes Road downstream of the working face exhibited a combined arithmetic mean concentration (20 CFU/m^3) that was higher than any other combined concentration (refer to Figure 1). The samples collected on Bank Road near the perimeter fence exhibited the lowest combined arithmetic concentration (5 CFU/m^3) when compared to all other sample locations. Although the taxonomic ranking varied slightly in both sampling locations, the identifiable species were consistent with those found at the working face. The samples collected in a field behind a church on Old Colerain showed differing results over the two day sampling period. On the first day of sampling (prevailing wind conditions defined the sample location as upwind), no detectable concentration was found. However, the second day of sampling resulted in an arithmetic mean concentration of 32 CFU/m^3 with enteric bacterial species consistent with those identified at the working face. This unexpected result may have been due to consistently changing wind directions on the second day of sampling. On the first day of sampling, the perceived wind speed was less and more stable in direction than on the second day.

Summary results of the air samples for fungal spore counts and endotoxins are presented in Table 4. The concentration of fungal spores at various locations in and around the periphery of the landfill revealed no uniquely distinguishing findings. The levels were similar to or lower than those observed at the church field. However, the concentrations collected in the cab of the compactor were consistently higher than all other sample concentrations. This is likely the direct result of the disruptive activity of the compactor on the landfill contents (and the fungal reservoirs present within). As with the fungal spore results, the endotoxin levels on-site and downwind of the municipal landfill were similar to those samples collected at the church field. Similarly, the samples collected in the compactor cap were marginally above those from all other sample locations. Overall, the concentrations observed were well below the criteria suggested by Rylander.

DISCUSSION

The sampling results do not exceed the applicable occupational or environmental criteria. However, windy weather conditions may have adversely affected the collection efficiency of the samplers used, which would result in under-estimation of the actual concentrations.

The enteric bacterial concentrations and isolated species from air samples collected on and around the periphery of the Rumpke landfill are consistent with bioaerosol studies of municipal landfills reported in the literature. In an investigation of a sanitary landfill in Finland, Rahkonen, *et al.* [1987] documented airborne concentrations of total coliform bacteria (from area samples collected with Andersen six-stage viable cascade impactors) during the summer, autumn, and winter seasons of 14, 29, and 24 CFU/m^3, respectively. [38] These concentrations correlate with those found in the area samples collected at the Rumpke landfill. Rahkonen and Ettala [1990] in a similar investigation of two Finlandian sanitary landfills identified genera of *Pseudomonas*, *Enterobacter*, *Klebsiella*, *Rahnella*, *Flavobacterium*, and *Achromobacter* in air samples collected with Andersen six-stage viable cascade impactors.[39] In 67% of the collected samples, gram-negative bacteria concentrations exceeded 1000 CFU/m^3. *Klebsiella* has been recommended by the American Society for Testing and Materials as one of the indicator organisms for assessing airborne microorganism concentrations at municipal solid-waste processing facilities.[40] *Klebsiella* was isolated from samples of three of the study sampling locations including the location at Hughes Road, downstream of the odor control system, and at the church field.

Acceptable levels of airborne microorganisms (fungi, total bacteria, or enteric bacteria) or their metabolic products have not been established. This absence of exposure criteria results primarily from the varying immunogenic susceptibilities of individuals and a limited understanding of the relationship between exposure concentrations and the initiation of disease. Combining the disciplines of medicine, epidemiology, and industrial hygiene for each unique situation may provide insight into the relationships between health effects and exposure.

CONCLUSIONS

Industrial hygiene sampling from on-site landfill locations and peripheral zones showed airborne contaminant concentrations well below criteria used for evaluating occupational exposures. The isolation of enteric bacterial species around the periphery of the landfill *only* supports the conclusion of possible microbiologic dissemination from the working face. The concentrations observed at the Rumpke landfill are consistent with bioaerosol studies of municipal landfills reported in the literature. The absence of definitive exposure criteria precludes the ability to assess the risks of such bioaerosol exposures. However, these results do indicate that the highest concentrations of particulates (including spore counts) measured were in the landfill compactor cab. A review of the literature indicates that significant exposures to total dust and respirable quartz have been associated with landfilling operations.[41,42] To protect the landfill compactor operators from potentially high exposures to respirable quartz and various genera of microorganisms, the retrofitting of the landfill compactors with air filters should be investigated.

RECOMMENDATIONS

Based on the results of personal air monitoring, the following recommendations are provided to improve health and safety conditions for employees at the Rumpke landfill.

1. To protect the landfill compactor operators from exposure to airborne concentrations of respirable quartz and various genera of microorganisms, the landfill compactors (and other heavy equipment) should be retrofitted with air cleaning devices. Engineering control modifications to the compactors, loaders, and bulldozers in the form of cab retrofits with HEPA filtration and positive pressurization, can significantly reduce the infiltration of outdoor contaminant sources.

2. Personal exposures of landfill compactor operators and other heavy equipment operators should be characterized by periodically conducting personal breathing zone air sampling for hydrogen sulfide, total particulate and respirable particulates during normal landfilling operations. Respirable particulate samples should be analyzed for silica content (i.e., percent quartz, cristobalite, etc.). Quartz was detected in total particulate samples collected by the NIOSH investigators at the Rumpke Landfill and respirable silica exposures have been documented in heavy equipment operators at other landfilling operations. Excavation, transport, and compaction of soil used for daily cover can create considerable dust resulting in exposure to airborne soil containing silica.

3. The episodic nature of refuse compaction and soil delivery and dissemination can result in extremes between dusty conditions to relatively dust free. The wastestreams at landfills are known to vary considerably; residues containing heavy metals and other toxic materials can become airborne when they are disposed. Construction debris may also contain asbestos-containing materials. Therefore, because of the difficulty in ascertaining which loads of refuse or what specific conditions may result in increased risk of exposure to employees, respiratory protection consisting of high efficiency particulate air (HEPA) filters should be provided and worn by all employees exposed to the dusts from materials intended for landfill disposal. This includes silica-containing soil used for cover at the working face. Mechanics servicing equipment contaminated with hazardous residues should also use respiratory protection. A complete employee respiratory protection program should be developed. The minimum standards for such a program are described in the Occupational Safety and Health Administration (OSHA) General Industry Standards, 29 CFR 1910.134.

4. Previous NIOSH studies have indicated that engine noise from heavy equipment used at municipal landfills can result in levels to equipment operators that exceed the OSHA PEL of 90 dB(A) for an 8-hour TWA.[42] Therefore, it is advisable to conduct a noise measurement survey to determine heavy equipment operators actual exposure.

5. Employees should be encouraged to shower before leaving the facility each day and should not be allowed to leave the site with any soiled work uniforms. The use of Tyvek® suits, to be worn over the work uniform should be available for situations when extremely dusty conditions are present. The use of a Tyvek® suit can, however, increase the possibility of heat stress in the warmer summer months. A heat stress monitoring program may need to be implemented.

6. Eating, drinking, and smoking should occur only in break areas and employees should be informed of the importance of handwashing to reduce the risk of dermal exposure and the ingestion hazards related to toxic materials.

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Table 1

Air sampling results for total and respirable particulates
Rumpke Landfill, Colerain Township, Ohio
HETA 96-0109
April 1996

Sample			milligram/cubic meter (mg/m^3)		
Location	Date	Time (minutes)	Total Particulate	Respirable Particulate	Real-time particulates§ (less than 10 micrometers)
Perimeter Locations					
Bank Road	4/3	NA	NA	NA	0.021
	4/11	NA	NA	NA	0.029
Hughes Road	4/3	NA	NA	NA	0.013
	4/11	NA	NA	NA	0.029
Old Colerain	4/3	NA	NA	NA	0.005
	4/11	NA	NA	NA	0.009
Locations Inside the Landfill					
Odor Control (barn)	4/3	NA	NA	NA	0.143
	4/11	NA	NA	NA	0.085
Working Face	4/3	375	0.27	ND	0.020
	4/11	348	0.29	ND	0.025
Compactor cab	4/3	382	0.34*	0.12	NA
	4/11	351 - 353	0.58#	ND	NA
Occupational Exposure Criteria:					
NIOSH Recommended Exposure Limit			no REL†	no REL†	no REL†
OSHA Permissible Exposure Limit			15‡ *8-hour TWA*	5‡ *8-hour TWA*	15‡ *8-hour TWA*
ACGIH Threshold Limit Value			10‡ *8-hour TWA*	3‡ *8-hour TWA*	10‡ *8-hour TWA*

NA - not applicable, sample not collected at this location.
ND - nondetectable, analyte not found at this location.
TWA - time-weighted average.
§ - integrated over an approximate two-hour period.
* - this sample contained a trace quantity of quartz (approximately 8%).
# - this sample contained 0.11 mg/m^3 or 19% quartz.
† - On August 1, 1988, NIOSH concluded that the documentation cited by OSHA was inadequate to support the proposed PEL.
‡ - for particulates not otherwise regulated by OSHA or not otherwise classified by ACGIH.

Table 2

Air sampling results for sulfur compounds and volatile organic chemicals
Rumpke Landfill, Colerain Township, Ohio
HETA 96-0109
April 1996

Sample			parts per million (ppm)		
Location	Date	Time (minutes)	Hydrogen sulfide (H_2S)	Other sulfur compounds	Volatile organic chemicals (total hydrocarbons)†
Perimeter Locations					
Bank Road	4/3	172 - 383	Trace	NA	Trace
	4/11	453	Trace	NA	ND
Hughes Road	4/3	211 - 367	Trace	NA	ND
	4/11	431	Trace	NA	ND
Old Colerain	4/3	149 - 327	Trace	NA	ND
	4/11	294 - 465	Trace	NA	ND
Locations Inside the Landfill					
Odor Control (barn)	4/3	125	ND	NA	ND
	4/11	334	Trace	ND	ND
Working Face	4/3	169 - 375	Trace	NA	ND
	4/11	345 - 348	fault	ND	ND
Compactor cab	4/3	134 - 382	Trace	NA	3.73 mg/m^3
	4/11	52 - 356	ND - fault	Trace	1.40 mg/m^3
Occupational Exposure Criteria:					
NIOSH Recommended Exposure Limit			10 (*10-min. Ceiling*)		‡350 mg/m^3
OSHA Permissible Exposure Limit			20 *Ceiling* 50 (*10-min. Maximum*)		‡525 mg/m^3
ACGIH Threshold Limit Value			10 *8-hour TWA* 15 (*15-min. Ceiling*)		‡525 mg/m^3

NA - not applicable, sample not collected at this location.
ND - nondetectable, analyte not found at this location.
TWA - time-weighted average
fault - sample pump failure
† - total hydrocarbons quantitation was performed using standards spiked from a bulk Stoddard Solvent
‡ - stoddard solvent criteria used for comparison purposes

Table 3

Results of sampling for culturable enteric bacteria
Rumpke Landfill, Colerain Township, Ohio
HETA 96-0109
April 1996

Sample Location	Sample Collection Date	Mean Concentration (CFU/m^3)	Standard Deviation	Predominant Genera
Hughes Road (dw)	4/3/96	30	26	*Ps.c>Ac.g>Ps.f*
Hughes Road (dw)	4/11/96	10	9	*Ps.f*>Yeast=*Kl.o>Pa.a=Ps.c*
Bank Road (uw)	4/3/96	4	6	*Ac.g=En.a=Pa.a=Ps.f*
Bank Road (uw)	4/11/96	6	6	Yeast>*En.a>Ps.f=Ra.a*
Church (uw)	4/3/96	0	0	
Church (uw/dw)	4/11/96	32	24	*Ps.f>Ps.c=Ra.a>Ag.r= Kl.o*=Yeast>*En.a*
Odor Control (dw)	4/3/96	11	5	*Ac.g>Kl.o=Ps.c> Pa.a=Ra.a=Ps.f*
Odor Control (dw)	4/11/96	10	17	*Ac.g=Ps.f*
Working Face (uw)	4/3/96	0	0	
Working Face (dw)	4/11/96	21	10	*Ra.a>Pa.a*=Yeast> *En.a>Ps.f>Ac.g=Ag.r*

Note: *Ac.g = Acinetobacter genospecies*; *Ag.r = Agrobacterium rhizogenes*; *En.a = Enterobacter agglomerans*; *Kl.o = Klebsiella oxytoca*; *Pa.a = Pantoea agglomerans*; *Ps.c = Pseudomonas cichorii*; *Ps.f = Pseudomonas fluorescens*; *Ra.a = Rahnella aquatilis*; Yeast = yeast; uw = upwind; dw = downwind

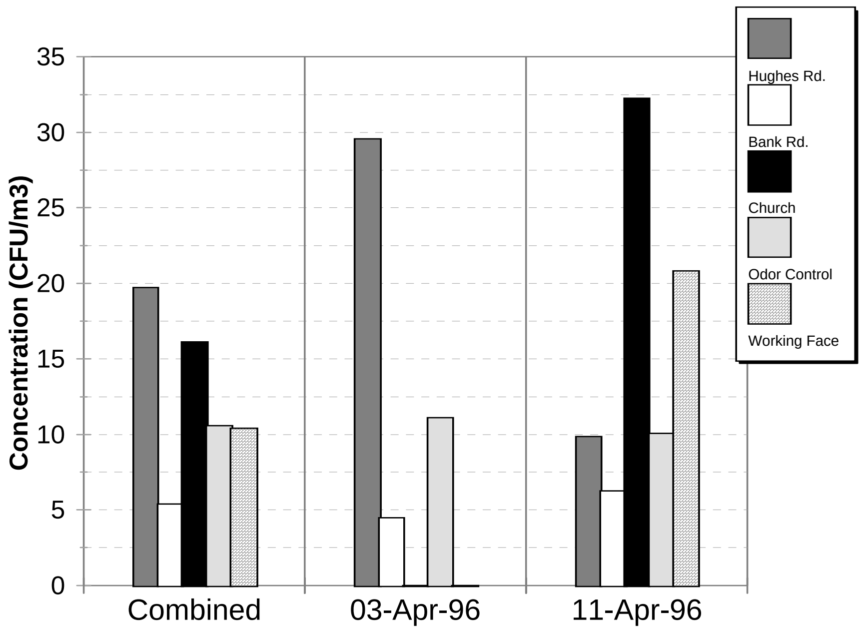
Table 4

Results of sampling for fungal spores and endotoxins
Rumpke Landfill, Colerain Township, Ohio
HETA 96-0109
April 1996

SAMPLE LOCATION	SAMPLE DATE	SPORES (spores/m^3)	ENDOTOXIN (EU/m^3)
Bank Road	April 3, 1996	15500	1.0
	April 11, 1996	5400	2.2
Hughes Road	April 3, 1996	19300	1.1
	April 11, 1996	16400	1.6
Church Field	April 3, 1996	40700	1.4
	April 11, 1996	9600	1.3
Working Face	April 3, 1996	22400	1.9
	April 11, 1996	9700	1.4
Compactor Cab	April 3, 1996	59800	2.4
	April 11, 1996	62800	4.4

Figure 1

Results of Sampling for Culturable Enteric Bacteria
Rumpke Landfill, Colerain Township, Ohio
HETA 96-0109
April 1996



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