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METROPOLITAN SEWER DISTRICT
MILL CREEK FACILITY
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I. SUMMARY

In June 1991, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request to conduct a health hazard evaluation (HHE) at the Metropolitan Sewer District (MSD), Mill Creek Facility, in Cincinnati, Ohio. The employees expressed concern over potential exposures to sulfur dioxide, nitrogen oxides, inorganic acids, metals, dioxins/furans, and bacteria in the sewer sludge dewatering and incineration buildings. In response to this request, an initial site visit was conducted at MSD on October 16-17, 1991, and a return visit was made on November 13, 1991.

Personal breathing zone and area air samples, short-term area air samples, surface wipe samples, and bulk material samples were collected by NIOSH investigators. Low levels [in the range of 1 to 68 micrograms per cubic meter ($\mu g/m^3$)] of aluminum, chromium, iron, magnesium, nickel, and zinc were detected in personal breathing zone air samples. Surface concentrations of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin equivalents ranged from 0.004 to 0.204 nanograms per sample. Low levels [in the range of 0.037 to 0.06 milligrams per cubic meter (mg/m^3)] of hydrochloric and sulfuric acid were detected in personal breathing zone samples and in the roof area air sample. Respirable silica was not detected in the area air samples at a limit of detection (LOD) ranging from 21.8 to 22.5 $\mu g/m^3$. One short-term respirable silica sample was not detected at a LOD of 71 $\mu g/m^3$. Analysis of bulk samples of dewatered sludge and dust found that 60-75% of the materials were respirable size particles (<10 micrometers in diameter) indicating a potential inhalation hazard. Small amounts (3 to 3700 µg/gram) of heavy metals (cadmium, chromium, lead, nickel, and zinc), 4.4-15% quartz, and higher aliphatic hydrocarbons (C_{11}-C_{21} range) were found in the bulk samples. Low concentrations of benzene (0.03 mg/m^3) and tetrahydrofuran (0.25 mg/m^3), carbon dioxide levels of approximately 550-1050 parts per million (ppm), and traces of ammonia and nitrous fumes were detected in area air samples in the dewatering press area.

Contaminant concentrations in the air and surface samples collected did not exceed current environmental evaluation criteria for the substances investigated. Concentrations of cadmium, chromium, lead, nickel, and quartz in dewatered sludge and surface dusts represent potential ingestion and inhalation hazards. Employees did not report health complaints at the time of the site visits. The composition of the incoming waste stream and consequently the sewer sludge is constantly changing; therefore, it is difficult to characterize average exposures. Recommendations are given to prevent contact with contaminated materials.

KEYWORDS: SIC 4952 (Sewerage Systems), multiple hearth incinerators, metals, respirable silica (quartz), volatile organic compounds, polychlorinated dibenzo-*p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs).

II. INTRODUCTION

In June 1991, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request to conduct a health hazard evaluation (HHE) at the Metropolitan Sewer District (MSD) in Cincinnati, Ohio. The employees expressed concern over potential exposures to sulfur dioxide, nitrogen oxides, inorganic acids, metals, dioxins/furans, and bacteria in the sewer sludge dewatering and incineration buildings. In response to this request, an initial site visit was conducted at MSD on October 16-17, 1991. A return visit was made on November 13, 1991. Preliminary sampling results were reported in a letter dated November 15, 1991.

III. BACKGROUND

There are approximately 60 employees on three shifts with the potential for exposure in the sewer sludge dewatering and incineration buildings. There are three job categories in the two buildings: operators, maintenance workers, and laborers.

Sewer sludge enters the two-story dewatering building after undergoing anaerobic digestion and chlorination treatment and is mixed with a polymer which neutralizes the charge of the sludge causing free water to fall out. The first floor contains sixteen pumps which serve sixteen filter presses on the second floor. The free-fall water goes back to the processing area. The polymer used to thicken the sludge contains aminomethylated polyacrylamide, approximately 6.8% by weight. This substance is listed as an eye, skin, and respiratory irritant on the material safety data sheet (MSDS) for the product (Diatec Environmental, Flocculent®).

According to MSD staff, the general ventilation system in the dewatering building was designed to deliver 10 air changes per hour (ach). At the time of the two site visits, windows and doors were open throughout the building. Employees open the windows whenever they wish. It was reported that there was a past history of hydrogen sulfide (H_2S) exposure from the dewatering process which was modified in the late 1980s.

Two series of conveyor belts are used to transfer the dewatered sludge to the incinerator building. The incinerator building contained four multiple-hearth incinerators and two others that were in the process of being dismantled. The incinerator removal process appeared dusty during the first site visit; therefore, sampling was conducted for respirable silica during the second site visit. Two new incinerators were to be installed. If there is an incinerator malfunction, the sludge is loaded into large bins which are then disposed of at a sanitary landfill. Excess sludge is cleaned up using non-potable city water. The multiple-hearth incinerators used by MSD are of a typical design, originally developed for roasting ores, and first used for sewage sludge in Dearborn, Michigan in 1934.[1,2] The outer shell of the MSD incinerators are constructed of steel, lined with refractory material, and surrounded by a series of horizontal refractory hearths. The sludge is dried in the upper hearths, burned in the central hearths, and the resulting ash cools in the lower hearths.[3]

The MSD incinerators were connected to two high-efficiency venturi/impingement tray scrubbers to control odor and particulate matter. The incinerators had an emergency system of dampers to by-pass the scrubbers if necessary. The fly ash and other debris from the incineration process was landfilled. The operators generally worked in climate-controlled rooms. Hard hats and steel-toed safety shoes were worn by employees in the two buildings. Hearing protection was required in the incinerator dismantling area.

Sewer sludge incinerators may emit significant quantities of pollutants, including: 1) particulate matter, 2) metals (cadmium, chromium, copper, nickel, lead, and zinc), 3) carbon monoxide (CO), 4) nitrogen oxides (NO_x), 5) sulfur dioxide (SO_2), and 6) unburned hydrocarbons.[1,4,5] Traces of dioxins/furans are also generated through the burning of chlorinated organic material.[6] The formation mechanism is unknown. Clement and associates in a 1987 study looked at stack emissions from a municipal sewer sludge incinerator and found the dibenzo-*p*-dioxins/polychlorinated dibenzofurans (PCDDs/PCFDs) levels to be lower than that found in previous studies of municipal refuse incinerators.[6-9] These substances are generated during the process stage and thus are potential occupational exposures to employees with the equipment inside the building and on the roof.

The results of previous environmental monitoring of MSD facilities were reviewed. Area air samples for trace metals were collected by MSD in November 1984, in the incinerator building and the filter floor. Concentrations of the metals, with the exception of phosphorus in the incinerator building, were relatively low. It should be noted that, in this case, area air samples are not representative of personal exposures since no employees worked in that area for extended periods of time. The phosphorus level was 0.14 milligrams per cubic meter (mg/m^3) which exceeded the environmental criteria of 0.1 mg/m^3. In June 1985, area air sampling for sulfur dioxide (SO_2) and sulfite ion (SO_3) was conducted inside and outside of the incinerator building. The concentrations of SO_3 were non-detectable. The SO_2 concentrations were within the occupational evaluation criteria (1.23 mg/m^3 and 1.02 mg/m^3, inside and outside the building, respectively).

Several previous investigations have been completed by NIOSH at MSD facilities. A survey conducted in March 1987, (HETA 87-157) looked at the sludge dewatering area at the Mill Creek facility.[10] The dewatering process was in the process of being renovated and not functioning as designed; therefore, it could not be determined whether a health hazard existed in that portion of the facility.

IV. STUDY DESIGN AND METHODS

A. Bulk Samples

A bulk sample of material deposited on incinerator building wall on the sixth floor and a bulk sample of the dust from the stairwell entrance to the roof were analyzed using a polarized light microscopy with and without dispersion liquid to determine if the particles were of respirable size (< 10 micrometers (µm)). These samples were also analyzed for percent quartz and percent cristobalite using x-ray diffraction (NIOSH Method 7500).[11] The limit of detection (LOD) and limit of quantitation (LOQ) for quartz are 3.8% and 7.5%, respectively. The LOD and LOQ for cristobalite are 0.75% and 1.5%, respectively.

A bulk sample of dewatered sludge was collected and submitted for qualitative analysis of volatile organic compounds to determine potential exposures. A portion of the sludge was extracted with carbon disulfide in an ultrasonic bath for 15 minutes. An aliquot of this solution was screened by gas chromatography-mass spectroscopy (GC-MS). Another portion of the sludge was heated and analyzed directly by GC-MS using a thermal desorption system to see if additional potential hazards would be present during the heating process.

Bulk samples of the dewatered sludge, debris from the sixth floor incinerator wall, dust from the stairwell entrance to the roof, and a substance from under the conveyor belt were collected and submitted for trace metal analyses. Following weighing and acid digestion, the samples were analyzed for twenty-four trace metals by inductively coupled plasma-atomic emission spectrometry, according to NIOSH Method 7300.[12] The LOQs are listed in Table 2.

B. Gases and Vapors

Short-term area (grab) air sample measurements were taken in both buildings for ammonia, carbon dioxide, carbon monoxide, hydrogen sulfide, nitrous fumes, sulfur dioxide, and total hydrocarbons using the Draeger® gas detection system with colormetric tubes as a screening device to see if further sampling was needed. Real-time carbon dioxide levels were measured in the same areas using a Gastech® Model RI-411A, portable CO_2 meter.

C. Volatile Organic Compounds

In November 1991, matched pairs of area air samples were collected in four areas for qualitative and quantitation analyses of volatile organic compounds. Samples were collected on charcoal tubes at a flowrate of 0.2 liters per minute (l/min). The charcoal tubes were desorbed with carbon disulfide and screened by GC-flame ionization detector (FID). One set of samples was used for qualitative analysis to identify major constituents by GS/MS analysis. Major constituents identified were then subsequently quantitatively analyzed in the paired samples (NIOSH Methods 1003, 1500, and 1609).[13-15] Total hydrocarbons were quantitated against hexane. The analytical LODs for toluene, 1,1,1-trichloroethane, and tetrahydrofuran were 0.01 milligrams (mg)/sample. The LODs for benzene and total hydrocarbons were 0.002 mg/sample and 0.1 mg/sample, respectively. The LOQs for toluene, 1,1,1-trichloroethane, and tetrahydrofuran were 0.033 mg/sample. The LOQs for benzene and total hydrocarbons were 0.0064 mg/sample and 0.33 mg/sample, respectively.

D. Metals

Seven personal breathing zone air samples and three area air samples were collected on mixed-cellulose ester filters (37 millimeter (mm) diameter, 0.8 micrometer (µm) pore size) using a flowrate of 2.0 l/min. Samples were collected for periods as near as possible to entire workshifts (6 to 7 hours). The samples were analyzed for metals according to NIOSH Method 7300.[12] In the laboratory, the samples were wet-ashed with concentrated nitric and perchloric acids and the residues were dissolved in a dilute solution of the same acids. The resulting sample solutions were analyzed by inductively coupled plasma (ICP) atomic emission spectrometry. The LOQs for the major metals detected are listed in Table 6.

E. Respirable Silica and Cristobalite

Seven area air samples for respirable dust (aerodynamic diameter less than 10 µm) were collected in the incineration building since the area had appeared dusty during the first site visit. The samples were collected at a flowrate of 1.7 l/min using 10 mm nylon cyclones mounted in series with pre-weighed polyvinyl chloride (PVC) filters (37 mm diameter, 5 µm pore size). They were analyzed for quartz and cristobalite content with x-ray diffraction. Samples were analyzed according to NIOSH Method 7500[11] with the following modifications: a) the filters were dissolved in tetrahydrofuran rather than being ashed in a furnace, and, b) standards and samples were run concurrently and an external calibration curve was prepared from the integrated intensities rather than the suggested normalization procedure. The analytical LOD was 15 µg per filter and the LOQ was 30 µg per filter.

F. Inorganic Acids

Ten personal breathing zone samples and three area air samples were collected on silica gel tubes at a flowrate of 0.2 l/min and analyzed for hydrofluoric acid, hydrochloric acid, hydrobromic acid, phosphoric acid, sulfuric acid, and nitric acid according to NIOSH Method 7903.[16] The "A" and "B" sections of each silica gel tube were separately desorbed in eluent and heated in a boiling water bath for ten minutes. The eluent was analyzed by ion chromatography and liquid standards were prepared and analyzed with the samples. The analytical LOD for hydrofluoric acid, hydrochloric acid, hydrobromic acid, sulfuric acid, and nitric acid was 3 micrograms (µg)/sample and the analytical LOD for phosphoric acid was 30 µg/sample. The LOQ for hydrobromic acid, sulfuric acid, and nitric acid was 6.8 µg/sample, 6.9 µg/sample for hydrochloric acid, 7.1 µg/sample for hydrofluoric acid, and for phosphoric acid was 69 µg/sample.

G. Dioxins/Furans

Three surface wipe samples were collected in the filter press area, the sixth floor of the incinerator building, and on the incinerator building roof under the stacks to assess the surface concentrations of polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). The surface wipe samples were used as a screening device and collected using 3" x 3" Soxhlet-extracted cotton gauze pads which had been wetted with 8 milliliters (ml) of pesticide-grade hexane. The sampling procedure consisted of marking the boundaries of a 100 square centimeter (cm^2) area on the desired surface and wiping this area with the gauze pad. The sample pad was held with a gloved hand; a fresh non-linear polyethylene, unplasticized glove was used for each sample. The surface was wiped in two directions (the second direction was at a 90° angle to the first direction). Each gauze pad was used to wipe only one area. The gauze pad sample was placed in a glass sample container equipped with a Teflon-lined lid. The wipe samples were extracted with toluene for 16 hours using a Soxhlet apparatus to dissolve the PCDD and PCDF from the samples. The resulting toluene solution was concentrated to near dryness on a rotary evaporator. An extensive purification process was then used to prepare the samples for analysis.

The surface samples are analyzed using Resource Conservation and Recovery Act (RCRA) Method 8280 by a GC/MS equipped with a DB-5 (screening) column and by DB-17 and SP 2331 columns in tandem (for isomer confirmation). Selected C^{13} and Cl^{37} labeled PCDD and PCDF isomers were included as internal standards and recovery (surrogate) standards.

Analyses were performed to measure total *tetra*-, *penta*-, *hexa*-, *hepta*-, and octachlorinated dibenzofurans; total *tetra*-, *penta*-, *hexa*-, *hepta*-, and octachlorinated dibenzodioxins; and specific PCDD and PCDF isomers containing chlorine substitution in the 2, 3, 7, and 8 positions. The analytical LODs were variable and ranged between 1 and 40.7 picograms per sample (pg/sample).

V. EVALUATION CRITERIA

In order to assess the hazards posed by workplace exposures, industrial hygienists use a variety of environmental evaluation criteria. These criteria propose exposure levels to which most employees may be exposed for a normal working lifetime without adverse health effects. These levels do not take into consideration individual susceptibility such as pre-exiting medical conditions or possible interactions with other agents or environmental conditions. Evaluation criteria change over time with the availability of new toxicologic data.

There are three primary sources of environmental evaluation criteria for the workplace: 1) NIOSH Recommended Exposure Limits (RELs)[17], 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs®)[18], and 3) the U.S. Department of Labor Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[19] The OSHA PELs may include the feasibility of controlling exposure in various industries where the agents are used; whereas, the 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.

A. Dioxins/Furans

Polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are two series of tricyclic aromatic compounds. The number of chlorine atoms can vary between 1 and 8 (mono- through octa-chloro homologs), resulting in 75 PCDDs and 135 PCDF positional isomers.

The toxic effects of these compounds are associated with the number and specific placement of the chlorine atoms in the molecule. The *tetra*-, *penta*- and hexachlorinated isomer groups exhibit greater toxicity than the other chlorinated forms.[20-22] PCDDs and PCDFs with chlorine at positions 2,3,7, and 8 are particularly toxic.[23-25] PCDDs and PCDFs are highly toxic in experimental animals when administered acutely, subchronically, or chronically.[26-33] Toxic effects include severe weight loss, liver necrosis and hypertrophy, skin lesions, immunosuppression, reproductive toxicity, teratogenesis and death. Exposure to PCDD can cause chloracne and liver toxicity in humans.[31,34]

NIOSH recommends that 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) be regarded as a potential occupational carcinogen based on a number of reliable studies demonstrating carcinogenicity in rats and mice.[31] NIOSH recommends that occupational exposures to 2,3,7,8-TCDD be controlled to the lowest feasible level, and that decontamination measures be used for 2,3,7,8-TCDD-contaminated work environments. Due to the inadequately-defined study populations and the influences of mixed exposures, definite causal relationships between PCDF and PCDD exposure and carcinogenic effects in humans remain unclear.

Air and surface guideline criteria for PCDDs/PCDFs are expressed as 2,3,7,8-TCDD equivalents. 2,3,7,8-TCDD equivalents are defined as the concentration of 2,3,7,8-TCDD which, by itself, would exhibit the same biological potency as the mixture of structurally-related compounds, PCDDs and PCDFs, actually present in a sample. The procedure assumes certain weighting factors (ratios of toxicities) between 2,3,7,8-TCDD and the other PCDDs and PCDFs.[35] The weighting factors [called toxicity equivalency factors (TEFs) by EPA] were those proposed in 1987 by the EPA.[36] In a 1989, update to this document, the EPA adopted the International TEFs. Both the 1987, EPA and 1989, International TEFs are listed below:

TOXICITY EQUIVALENCY FACTORS

Compound	EPA-TEFs/87	I-TEFs/89
Mono-,Di-, and TriCDDs	0	0
2,3,7,8-TCDD	1	1
Other TCDDs	0.01	0
2,3,7,8-PeCDD	0.5	0.5
Other PeCDDs	0.005	0
2,3,7,8-HxCDDs	0.04	0.1

Other HxCDDs	0.0004	0
2,3,7,8-HpCDDs	0.001	0.01
Other HpCDDs	0.00001	0
OCDD	0	0.001
Mono-,Di-, and TriCDFs	0	0
2,3,7,8-TCDF	0.1	0.1
Other TCDFs	0.001	0
1,2,3,7,8-PeCDF	0.1	0.05
2,3,4,7,8-PeCDF	0.1	0.5
Other PeCDFs	0.001	0
2,3,7,8-HxCDFs	0.01	0.1
Other HxCDFs	0.0001	0
2,3,7,8-HpCDFs	0.001	0.01
Other HpCDFs	0.00001	0
OCDF	0	0.001

The concentrations of the PCDD and PCDF compounds are converted to TCDD equivalents by multiplying measured values by the appropriate factor. The TCDD equivalents are then summed and compared to the guideline value.

The National Research Council (NRC) released a report on acceptable levels of dioxin contamination in office buildings following transformer fires.[37] The exposure guidelines, for a single source contamination, adopted by a NRC subcommittee were 10 picograms per cubic meter (pg/m^3) for air and 25 nanograms per cubic meter (ng/m^2) for surfaces expressed as 2,3,7,8-TCDD equivalents calculated using the 1987 EPA TEFs.

B. Respirable Silica and Cristobalite

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.[38] The NIOSH RELs for respirable quartz and cristobalite, published in 1974, are 50 µg/m^3, as 10-hour time weighted averages (TWAs).[39] Based on data available more recently, NIOSH considers quartz and cristobalite to be potential human carcinogens and recommends exposures be reduced to the lowest feasible levels.[17] The OSHA PELs and the ACGIH TLVs are 100 and 50 µg/m^3 for respirable quartz and cristobalite, as 8-hour TWAs, respectively.[18,19]

C. Metals

A list of selected metals along with a brief summary of their primary health effects are presented in Table 1. The evaluation criteria for occupational exposures to these contaminants are included in Table 6.

D. Sulfur Dioxide

Sulfur dioxide is intensely irritating to the eyes, mucous membranes, and respiratory tract. It can cause burning of the eyes and tearing coughing and chest tightness. Exposure may cause severe breathing difficulties. It forms sulfurous acid on contact with moist membranes.[47] NIOSH, OSHA, and ACGIH have set an exposure limit of 2 parts per million (ppm) for sulfur dioxide.

E. Inorganic Acids

Hydrochloric acid is an eye, mucous membrane and skin irritant.[49] Exposure of the skin can cause burns, prolonged or repeated exposures may cause dermatitis. NIOSH, OSHA, and ACGIH have set an exposure limit of 5 ppm as a ceiling limit (not to be exceeded at any time). Sulfuric acid is a severe irritant of the respiratory tract, eyes, and skin.[49] Exposure can also cause dental erosion. NIOSH, OSHA, and ACGIH have set an exposure limit of 1 mg/m^3 for sulfuric acid.

F. Nitrogen Oxides

Nitrogen oxides (NO_x) include several compounds including nitrous oxide (N_2O), nitric oxide (NO), and nitrogen dioxide (NO_2). NO_x gases may produce irritation of the eyes and mucous membranes. Exposure to high concentrations of NO_x may result in severe pulmonary irritation and methemoglobinemia. Chronic exposure may result in pulmonary dysfunction - the most common symptom of which is shortness of breath upon exertion.[17,47] NIOSH, OSHA, and ACGIH have set exposure limits of 25 ppm, none, and 50 ppm for nitrous oxide; 25 ppm, 25 ppm, and none for nitric oxide; and 1 ppm, 1 ppm, and 3 ppm for nitrogen dioxide.

G. Selected Organic Solvents

Acute benzene overexposure can cause central nervous system depression with symptoms such as headache, nausea, and drowsiness. Chronic exposure to benzene has been associated with the depression of the hematopoietic system and is associated with an increased incidence of leukemia and possibly multiple myeloma.[17,47] The NIOSH REL is 0.1 ppm and classifies benzene as a human carcinogen, the OSHA PEL is 1 ppm, the current ACGIH TLV® is 10 ppm as a suspected human carcinogen. ACGIH has proposed to lower the TLV® to 0.1 ppm and classify it as a proven human carcinogen.[18] Tetrahydrofuran can cause anesthetic effects and mild upper respiratory tract irritation. At high concentrations it is a central nervous system depressant.[17,47] The current evaluation criteria for tetrahydrofuran has been set at 590 mg/m^3 by the three agencies.

VI. RESULTS

A. Bulk Samples

The major metallic components of the bulk sludge samples were aluminum, calcium, iron, magnesium, phosphorus, and sodium [range: 530 - 340000 micrograms per gram (µg/g)] (Table 2). Lesser concentrations of cadmium (range: 3 - 410 µg/g); chromium (range: 61 - 780 µg/g); lead (range: 29 - 890 µg/g); nickel (range: 34 - 400 µg/g); and zinc (range: 230 - 3700 µg/g) were detected in the bulk samples. These results were similar to those found in the 1987 NIOSH site visit.[10]

The material collected from the incinerator building wall on the sixth floor contained 65-70% respirable particles and the sample from the stairwell entrance to the roof contained 70-75% respirable particles.

The chromatograms for the GC-MS analyses of the concentrated extract and thermally desorbed samples of dewatered sludge are presented in Figures 2 and 3, respectively. Both techniques gave similar results. The major components detected were higher boiling aliphatic hydrocarbons in the C_{11}-C_{21} range. Butylated hydroxytoluene (BHT) was also detected. The polyacrylamide polymer would not have been detected using this method.

The results of the analyses for percent quartz and cristobalite are shown in Table 3. The sample from the incinerator wall contained 4.4% quartz and 1.4% cristobalite. Both measurements were between the LOD and LOQ. The bulk sample collected in the stairwell to leading to the roof contained 15% quartz. It contained 1.2% cristobalite - a level between the LOD and LOQ. Both samples contained mica and feldspar interference peaks; therefore, the quartz content was analyzed using the secondary quartz peak. The semi-quantitative cristobalite values may reflect some minor interference.

B. Gases and Vapors

The results of short-term sampling for ammonia, carbon dioxide, carbon monoxide, hydrogen sulfide, nitrous fumes, sulfur dioxide, and total hydrocarbons are listed in Table 4. On the fifth floor of the incineration building, carbon dioxide levels of approximately 550 ppm and a trace of nitrous fumes were detected. On the second floor of the dewatering building, ammonia levels of approximately 1 ppm, carbon dioxide concentrations of 1050 and 900 ppm, and trace levels of nitrous fumes were detected. None of the other substances (carbon monoxide, hydrogen sulfide, sulfur dioxide, and total hydrocarbons) were detected. These measurements were below the respective occupational exposure criteria.

C. Volatile Organic Compounds

The area air samples collected in the north area and the south end of the dewatering floor, and the seventh floor of the incinerator building had similar chromatographs. A copy of the chromatograph with identified peaks is included as Figure 1. Compounds identified included siloxanes, various aliphatic hydrocarbons, THF, benzene, toluene, xylenes and higher aromatics, limonene, 1,1,1-trichloroethane, and a trace of other chlorinated hydrocarbons. The area air sample collected in the vicinity of the conveyor entrance into the incinerator building contained a trace amount of BHT and another unidentified alkyl phenol.

The results of the quantitative analyses are shown in Table 5. Toluene and 1,1,1-trichloroethane were not detected at the LOD of 0.01 mg/sample. Benzene was detected at a trace level (between the LOD and LOQ) in the area air sample collected at the south end of the dewatering presses. Tetrahydrofuran was also found in the same sample at a concentration of 0.25 mg/m^3. Total hydrocarbon concentrations ranged from non-detected to 4.2 mg/m^3. The detected concentrations were below respective evaluation criteria.

D. Metals

Personal breathing zone samples were collected for 2 laborers, 3 maintenance workers, 1 dewatering equipment operator, and 1 incinerator operator. Area samples were collected in the press area of the dewatering building, the fifth floor of the incinerator building, and on the roof of the incinerator building near the stacks. The results are presented in Table 6. Low concentrations of aluminum, chromium, iron, magnesium, nickel, and zinc (range: 1 µg/m^3 to 68 µg/m^3) were detected. None of the detected concentrations exceeded the respective occupational evaluation criteria.

E. Respirable Silica

The results for the seven area air samples collected for respirable silica (quartz) are presented in Table 7. Respirable silica was not detected in the area air samples at a LOD ranging from 21.8 to 22.5 µg/m^3. One short-term respirable silica sample was not detected at a LOD of 71 µg/m^3.

F. Inorganic Acids

The results of the personal breathing zone area air samples are presented in Table 8. There were no detectable concentrations of hydrofluoric acid, nitric acid, phosphoric acid, or hydrobromic acid. Hydrochloric acid was detected in two personal breathing zone samples (laborer - 0.038 mg/m^3 and incinerator plant operator - 0.06 mg/m^3) which were between the LOD and LOQ. Sulfuric acid was detected in the area sample from the roof of the incinerator building (0.037 mg/m^3) which was between the LOD and the LOQ. All concentrations detected were below the evaluation criteria from

NIOSH, OSHA, and ACGIH of 7 mg/m^3 for hydrochloric acid and 1 mg/m^3 for sulfuric acid. The "B" section of the silica gel tube contained more than 30% of the total analyte for the two hydrochloric acid samples and the one sulfuric acid sample, which indicated that the concentrations detected may be lower than the actual air concentrations.

G. Dioxins

Three surface wipe samples (Table 9) were collected for *tetra*-through *octa*-chlorinated PCDD and PCDF homologs and the 2,3,7,8-*tetra* isomers. These samples were collected from the filter press area, the sixth floor of the incineration building, and under the exhaust stacks on the roof of the incineration building. The calculated concentrations of TCDD-equivalents using the 1987, EPA TEFs ranged from 0.004 to 0.204 nanograms per square meter (ng/m^2). None of the samples were above the NRC guideline of 25 ng/m^2. These concentrations ranged from 0.014 to 0.484 ng/m^2 when calculated using the 1989 International TEFs. A field blank sample was found to contain less than 0.001 ng/m^2.

VII. DISCUSSION AND CONCLUSIONS

Concentrations of contaminants in the surface, area, and personal samples did not exceed established occupational evaluation criteria. The presence of heavy metals (cadmium, chromium, lead, nickel, and zinc) and respirable size dust particles in the sewer sludge indicates that there are potential ingestion and inhalation health hazards. There is also a potential inhalation hazard to respirable silica (quartz) from the clean-up of dust in the incineration building. The metal and volatile organic solvent contents of the sewer sludge found in this investigation are similar to a study conducted by NIOSH in 1987. The composition of the sludge is variable due to a changing incoming household and industrial waste stream. As a result, it is difficult to characterize average exposures. The type of industrial waste that enters the treatment plant depends upon the type of industries that are serviced and their respective control over hazardous effluents.

Biological sampling for bacteria and viruses was not conducted since the sludge at this point in the process had undergone chlorination and anaerobic digestion. Although few epidemiologic studies have investigated the health of wastewater treatment facility workers, health effects documented have been limited to acute, self-limited gastrointestinal illnesses.[50] Fanin and associates, in a 1985 study, found that bacteria and virus-containing aerosols increased within the boundaries of a newly activated sludge wastewater treatment plant.[51] The study found enteric viruses in low densities from the air emissions of the plant. At present, there is no suitable indicator organism for airborne pathogens from a sewage source.[52] Studies of the health effects among persons living close to wastewater treatment plants have not detected undue risk of infectious disease.[53] Other studies have indicated the potential for infection from the handling of untreated wastewater.[50] Four employees were interviewed out of approximately twenty workers on the first shift. The employees did not report any health complaints to NIOSH investigators during the two site visits.

VIII. RECOMMENDATIONS

1. Safety glasses should be worn throughout the two buildings to protect against splashes of non-potable water and dust.

2. Protective clothing, including gloves, should be worn when in direct contact with the polymer used in the dewatered sludge process.

3. Respirators approved by NIOSH for toxic dusts and mists should be worn in the incineration dismantling area during clean-up to protect against dust which might contain respirable silica. Whenever respirators are used (on a voluntary or required basis), the employer must provide a comprehensive respiratory program that meets OSHA requirements (29 CFR 1910.134).[54]

4. A no eating/drinking/smoking policy should be implemented in the incineration dismantling area because of potential for ingestion of metals and other substances in surface dusts.

5. Good personal hygiene practices should be followed to avoid additional exposure to trace heavy metals in sludge and dust, and biological agents in untreated material.

6. Rubber gloves should be worn when in direct contact with untreated wastewater or sludge or when the skin is broken from any cause.

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Copies of this report have been sent to:

1. Metropolitan Sewer District
2. American Federation of State, County and Municipal Employees, Ohio Council 8
3. OSHA, Region V
4. Confidential Requestor

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 7

Results of Area Samples for Respirable Silica

Metropolitan Sewer District
Cincinnati, Ohio
HETA 91-261

November 13, 1991

Job Title/ Location	Sample Sampling Time	Respirable Silica Volume (liters)	Concentration (TWA-µg/m^3)*
Second Floor-West Side	8:34 - 3:19	689	ND**
Third Floor-Ease Side Lockers	8:37 - 10:41	211	ND
Roof Under South Stacks	8:48 - 3:22	670	ND
Roof Under North Stacks	8:47 - 3:20	668	ND
Seventh Floor-On Ductwork	8:41 - 3:26	689	ND
Dewatering Area-South Side	8:30 - 3:05	672	ND
Seventh Floor- Windowsill Near Conveyor	8:40 - 3:25	689	ND

NIOSH Recommended Exposure Limit (REL): 50 µg/m^3#

OSHA Permissible Exposure Limit (PEL): 100 µg/m^3##

ACGIH Threshold Limit Value (TLV®): 50 µg/m^3##

Limit of Detection (LOD): 15 micrograms (µg)/filter
Limit of Quantitation (LOQ): 30 µg/filter

* - TWA-µg/m^3 - Time-weighted average-micrograms per cubic meter
\# - Ten hour TWA
\## - Eight Hour TWA
** - ND - None Detected, below the LOD

Table 6

Results of Personal Breathing Zone and Area Samples for Metals Using Inductively Coupled Plasma Emission Spectroscopy (ICP)

Metropolitan Sewer District
Cincinnati, Ohio
HETA 91-261

October 17, 1991

Job Title/ Location	Sampling Time	Sample Volume (liters)	Metal Concentrations (TWA-μg/m³)* Al	Cr	Fe	Mg	Ni	Zn
Personal:								
Laborer	7:35-11:19 12:10-3:01	790	47	3	68	19	3	3
Maintenance	7:38-2:59	882	8	ND**	22	3	ND	1
Maintenance	7:40-3:04	888	6	ND	9	2	ND	1
Maintenance	7:44-2:59	870	ND	ND	36	2	ND	1
Plant Operator/Incenerator	8:15-3:10	830	11	ND	31	2	ND	2
Laborer	7:31-11:18 12:10-3:03	800	24	1	33	9	1	3
Plant Operator/Dewatering	8:17-3:12	830	ND	ND	7	2	ND	ND
Area:								
Sixth Floor of Incinerator Building	8:45-3:35	820	7	ND	50	2	ND	2
Roof near Stacks	8:41-3:28	814	ND	ND	17	ND	ND	ND
Deck Between Dewatering Presses	8:20-3:10	820	6	ND	7	2	ND	ND
Limits of Quantitation (μg/filter)		5	1	1	2	1	1	

* - TWA-μg/m³ - Time-weighted average micrograms per cubic meter
** - ND - None Detected, below the LOQ

Metals	OSHA PELs (μg/m³)	NIOSH RELs (μg/m³)	ACGIH TLVs (μg/m³)
Al - Aluminum	15000	10000	10000
Cr - Chromium	1000	500	500
Fe - Iron	10000	5000	5000
Mg - Magnesium	10000	None	10000
Ni - Nickel	100	15	1000 (50 - proposed)
Zn - Zinc	10000	5000	10000

Table 8

Results of Personal Breathing Zone and Area Air Samples for Inorganic Acids

Metropolitan Sewer District
Cincinnati, Ohio
HETA 91-261

October 17, 1991

Job Title/ Location	Sampling Time	Sample Volume (liters)	Hydrochloric Acid Concentration (TWA-mg/m^3)*	Sulfuric Acid Concentration (TWA-mg/m^3)*
Personal:				
Laborer	7:31-11:19 12:10-3:01	80	0.038**#	ND##
Laborer	7:36-11:19 12:10-3:01	78	ND	ND
Plant Operator-Incinerator Area	8:14-3:10	83.2	0.06**#	ND
Maintenance	7:41-3:04	88.4	ND	ND
Maintenance	7:44-3:05	85.5	ND	ND
Maintenance	7:38-3:05	87.3	ND	ND
Plant Operator-Dewatering Area	8:16-3:12	82.4	ND	ND
Area:				
Roof of Incinerator Building	8:41-3:28	80.9	ND	0.037**#
Dewatering Area Between Presses	8:20-3:11	79.4	ND	ND
Sixth Floor of Incinerator Building	8:45-3:32	81.5	ND	ND
Limit of Detection (LOD) [mg/sample]			0.003	0.003
Limit of Quantitation (LOQ)[mg/sample]			0.007	0.007
NIOSH Recommended Exposure Limit (REL):			7 (ceiling)	1
OSHA Permissible Exposure Limit (PEL):				7 (ceiling) 1
ACGIH Threshold Limit Value (TLV®):			7.5 (ceiling)	1

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* - TWA-mg/m^3 - Time-weighted average milligrams per cubic meter
** - Between LOD and LOQ
# - More than 30% of analyte in Section B of silica gel tube
##- ND - None Detected, below the LOD

Table 9

Surface Concentrations of 2,3,7,8-TCDD* Equivalents

Metropolitan Sewer District
Cincinnati, Ohio
HETA 91-261

November 13, 1991

Sample Description	Results using 1987 TEFs#(ng/m^2)**	Results using 1989 TEFs##(ng/m^2)
Dewatering Building- Filter Press Area	0.007	0.016
Incinerator Building- Sixth Floor Beside Conveyor	0.204	0.484
Incinerator Building Roof Under Stacks	0.004	0.014

Evaluation Criteria: National Research Council Surface - 25.0 ng/m^2

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* - 2,3,7,8- TCDD - 2,3,7,8-tetrachlorodibenzo-*p*-dioxin.

#1987 TEFs - U.S. Environmental Protection Agency Toxicity Equivalency Factors.

##1989 TEFs - International Toxicity Equivalency Factors.

**ng/m^2 - nanograms per square meter of surface area.

Table 1

Health Effects Summary for Metals

Metropolitan Sewer District
Cincinnati, Ohio
HETA 91-261

Substance	Primary Health Effects
Aluminum	Metallic aluminum dust is considered a relatively benign "inert dust."[40]
Cadmium	NIOSH recommends that exposure to cadmium and its compounds be reduced to the lowest feasible level, as it is considered a potential carcinogen. NIOSH based this recommendation on epidemiologic evidence of a significant excess of cancer deaths among a group of cadmium production workers.[41] Chronic exposure has also been associated with gastrointestinal symptoms, emphysema, kidney disease, and rhinitis.[40]
Chromium	Chromium (Cr) exists in a variety of chemical forms and toxicity varies among the different forms. For example, elemental chromium is relatively non-toxic.[40] Other chromium compounds may cause skin irritation, sensitization, and allergic dermatitis. In the hexavalent form (Cr(VI)), Cr compounds are corrosive, and possibly carcinogenic. Until recently, the less water-soluble Cr(VI) forms were considered carcinogenic while the water-soluble forms were not considered carcinogenic. Recent epidemiological evidence indicates carcinogenicity among workers exposed to soluble Cr(VI) compounds.[42-46] Based on this new evidence, NIOSH recommends that all Cr(VI) compounds be considered as potential carcinogens.
Iron	Inhalation of iron oxide dust may cause a benign pneumoconiosis called siderosis.[47]
Lead	Chronic lead exposure has resulted in nephropathy (kidney damage), gastrointestinal disturbances, anemia, and neurologic effects.[44] These effects may be felt as weakness, fatigue, irritability, high blood pressure, mental deficiency, or slowed reaction times. Exposure also has been associated with infertility in both sexes and fetal damage.[48]
Nickel	Metallic nickel compounds cause sensitization dermatitis.[40] NIOSH considers nickel a potential carcinogen, as nickel refining has been associated with an increased risk of nasal and lung cancer.[49]
Magnesium	Magnesium can cause eye and nasal irritation.[49] Exposure has been associated with the development of metal fume fever.[17]
Zinc	Zinc has been associated with shortness of breath, minor lung function changes, and metal fume fever.[17,49]

Table 2

Results of Bulk Samples Analyses for Metals Using Inductively Coupled Plasma Emission Spectroscopy (ICP)

Metropolitan Sewer District
Cincinnati, Ohio
HETA 91-261

October 17, 1991

	Source				
Metal (µg/g)*	Dewatered Sludge	Incinerator Wall	Stairwell Entrance to Roof	Residue from Conveyor Leakage	LOQ (µg/g)
Aluminum	4400	30000	41000	4300	10
Barium	510	620	370	54	1
Beryllium	ND	1	2	ND	1
Calcium	14000	5000	74000	12000	5
Cadmium	3	410	400	6	1
Cobalt	4	16	23	2	1
Chromium	160	530	780	61	1
Copper	390	1900	2600	120	1
Iron	4900	10000	22000	3300	1
Lithium	ND	13	22	140	5
Magnesium	1600	6900	12000	16000	2
Manganese	160	750	1000	110	1
Molybdenum	13	41	46	49	1
Nickel	68	280	400	34	1
Lead	38	890	710	29	2
Phosphorus	5000	13000	19000	1200	10
Silver	14	57	70	3	1
Sodium	530	1900	2800	340000	20
Titanium	87	150	230	140	1
Tungsten	ND	10	20	ND	10
Vanadium	5	31	40	3	1
Yttrium	1	14	19	1	1
Zinc	230	1800	3700	540	1
Zirconium	ND	40	40	ND	10

* - µg/g - microgram per gram sample

10,000 µg/g = 1 percent by weight

Table 3

Results of Bulk Samples for Quartz and Cristobalite Content

Metropolitan Sewer District
Cincinnati, Ohio
HETA 91-261

November 13, 1991

Sample Location	Quartz (Percent)	Cristobalite (Percent)
Incinerator Wall-Sixth Floor	4.4%*	1.4%*
Incinerator Building-Stairwell to Roof	15%	1.2%*
Limit of Detection (LOD):	3.8%	0.75%
Limit of Quantitation (LOQ):	7.5%	1.5%

* - Between LOD and LOQ

Table 5

Results of Area Air Samples for Volatile Organic Compounds

Metropolitan Sewer District
Cincinnati, Ohio
HETA 91-261

November 13, 1991

Location	Sampling Time	Sample Volume (liters)	Benzene Concentration (TWA-mg/m^3)*	Tetrahydrofuran Concentration (TWA-mg/m^3)	Total Hydrocarbons Concentration (TWA-mg/m^3)
Dewatering Presses-North	8:25-3:11	80.7	ND#	ND	2.5**
Dewatering Presses-South	8:22-3:05	80.5	0.03**	0.25	4.2
Entrance of Conveyor into Incinerator	8:27-3:07	80	ND	ND	3.3**
Seventh Floor Incinerator Building	8:43-3:28	75.2	ND	ND	ND
LOD [mg/sample]			0.002	0.01	0.1
LOQ[mg/sample]			0.0064	0.033	0.33
NIOSH Recommended Exposure Limit (REL)			0.32	590	
OSHA Permissible Exposure Limit (PEL)			3.2	590	
ACGIH Threshold Limit: Value® (TLV®)			32 (proposed-0.3)	590	

* - TWA-mg/m^3 - Time-weighted average milligrams per cubic meter
** - Between LOD and LOQ
#- ND - None Detected, below the LOD

Table 4

Results of Direct Reading Survey for Ammonia, Carbon Dioxide, Carbon Monoxide, Hydrogen Sulfide, Nitrous Fumes, Sulfur Dioxide, and Total Hydrocarbons

Metropolitan Sewer District
Cincinnati, Ohio
HETA 91-261

October 17, 1991

Concentration (ppm)* [Limit of Detection]	Location Incineration Building 5th Floor	 Dewatering Building 2nd Floor
Ammonia [5 ppm]	ND**	1
Carbon Dioxide [5 ppm]	550	1050 (900)#
Carbon Monoxide [5 ppm]	ND	ND
Hydrogen Sulfide [1 ppm]	ND	ND
Nitrous Fumes [2 ppm]	Trace (< 1 ppm)	Trace (< 1ppm)
Sulfur Dioxide [1 ppm]	ND	ND
Total Hydrocarbons [100 ppm]	ND	ND

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* ppm - parts per million
** ND - none detected
\# - second measurement