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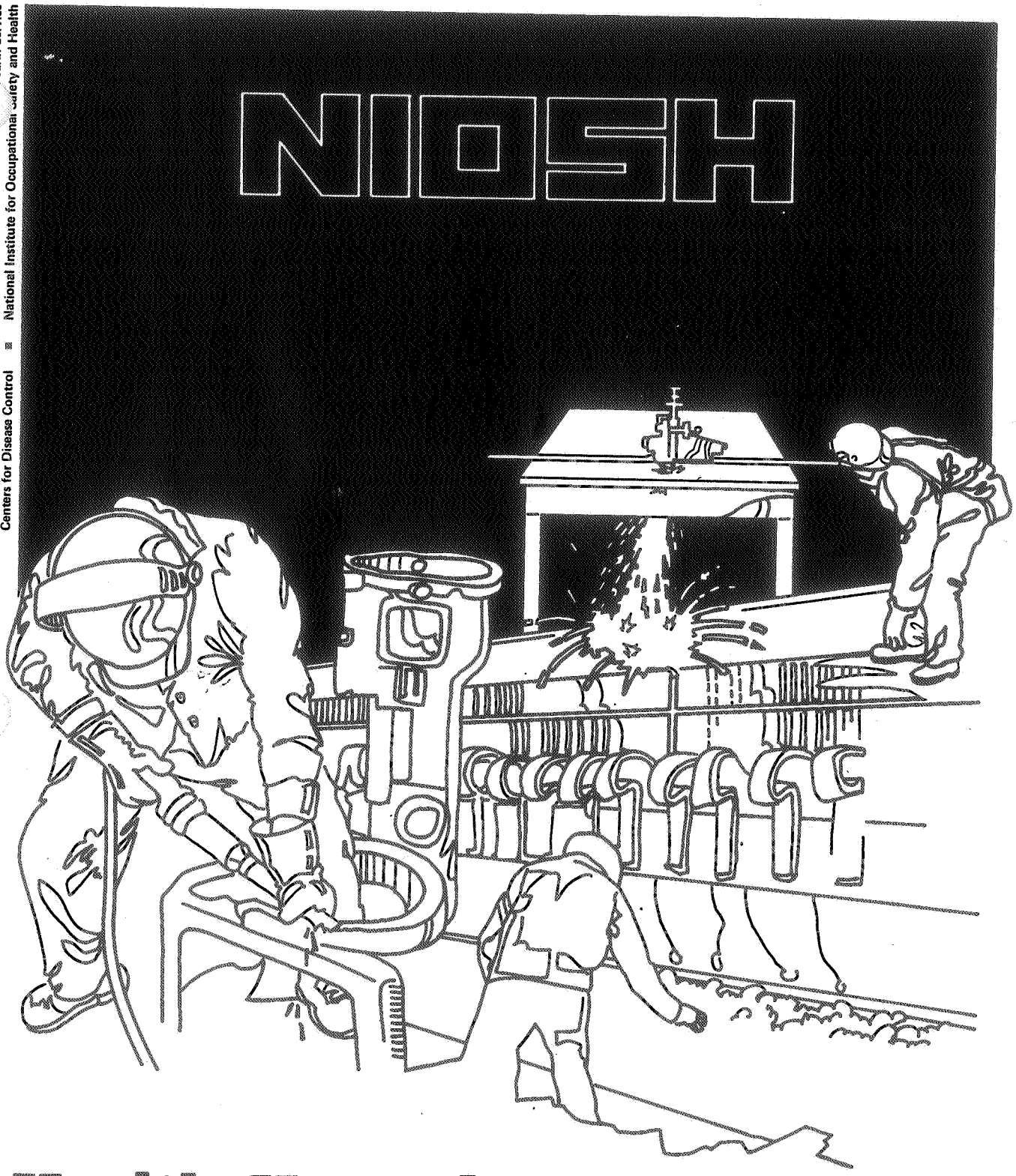

Health Hazard Evaluation Report

HETA 81-207-945
METROPOLITAN SEWER DISTRICT
CINCINNATI, OHIO

PREFACE

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

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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Metropolitan Sewer District
Cincinnati, Ohio

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I. SUMMARY

On February 23, 1981, the National Institute for Occupational Safety and Health (NIOSH) was requested by the City Health Commissioner of Cincinnati, Ohio, to evaluate an acute outbreak of illnesses (eye and nose irritation, nausea, dizziness, and vomiting) among six sewer workers excavating a collapsed sewer the previous day in an industrial section of the city.

On the same day a NIOSH medical and industrial hygiene team began an investigation to identify the etiology of the illnesses, locate their source, and determine the extent of injury to workers' health. NIOSH investigators used direct-reading instruments to determine the presence and concentrations of organic vapors in sewers, obtain area air samples for later identification of specific organic compounds, environmentally determine contaminant concentration upstream from the sewer collapse, and conduct medical interviews with affected employees at the work site. Follow-up investigations were conducted on March 2, 3, and 23, 1981.

During the initial investigation, NIOSH industrial hygienists found seven organic solvents in the sewers: 1,1,1-trichloroethane (TCE), (range 1.0 to 40.0 parts per million (ppm)), trichloroethylene, (range 0.4 to 7.3 ppm), toluene, (range non-detectable to 1.0 ppm), mineral spirits, (range 20 to 517 ppm), perchloroethylene, (range ND to 1.2 ppm), xylene, (range ND to 3.5 ppm), and chlorobenzene (range ND to 0.2 ppm). The two primary contaminants were TCE and mineral spirits, which increased in concentration from the work site to two discharge pipes from a nearby pigments plant, then decreased above the plant. Wastewater samples collected at the work site were highly acidic (pH 2.0). The sewer cave-in appeared to be caused by acidic wastewater discharge which had eroded the concrete.

A NIOSH physician conducted interviews with five of the most severely affected workers at the work site on February 23, 1981. Later (March 2, 3, and 23, 1981), the medical evaluation was expanded to include all workers involved with the sewer repair. Results showed 46 workers were exposed to sewer contaminants between February 17 and March 3, 1981. Twenty-seven of these exposed workers were symptomatic, eight had liver function test abnormalities; and six had hematologic test abnormalities. The medical questionnaire showed 28 (61%) of 46 workers had mucous membrane irritation, 59% had systemic effects, 33% had chest symptoms, and 15% had acute bronchitis. Development of adverse health effects were most acute on February 18, 1981, during sandbag barricading of industrial effluent, and on February 22, 1981, during sewer excavation.

Based on these environmental and medical results, NIOSH concluded that a health hazard from overexposure to industrial solvents existed while workers were repairing an industrial sewer in Cincinnati, Ohio. Protection of sewer workers from future incidents such as this should involve enforcement of wastewater regulations, adequate industrial hygiene and safety support, training and use of proper personal protective equipment, positive pressure (fresh air) sewer ventilation, and adequate medical surveillance of sewer workers. Specific recommendations are presented in Section VIII of this report.

KEYWORDS: SIC 4952 (Sewerage workers); 1,1,1-trichloroethane, mineral spirits, industrial effluents, organic pigments, acids. Toxic effects - liver and hematologic abnormalities, mucous membrane irritation, acute bronchitis.

II. INTRODUCTION

In February 1981, NIOSH received a request for a health hazard evaluation of Metropolitan Sewer District workers, Cincinnati, Ohio. The request was initiated by the City Health Commissioner of Cincinnati, Ohio, following worker exposure and illness to unknown contaminants while excavating a corroded sewer drain in an industrial section of the city on February 22, 1981. The Health Commissioner asked NIOSH to identify the contaminants, locate the source, and determine worker health effects from exposure.

NIOSH distributed Interim Report #1 in March 1981 which identified the contaminants and their source. In April 1981, Interim Report #2 was released which contained recommendations to reduce risks for employees working in sewers.

III. BACKGROUND

On February 19, 1981, a 30-foot-deep sewer in an industrial section of Cincinnati, Ohio, collapsed, bringing with it 20 tons of earth and leaving a hole 24 feet in diameter in the street. Three days later, several sewer workers were overcome by nausea, vomiting, dizziness, and eye and nose irritation while repairing the collapsed drain, and had to climb out of the sewer. Four other workers also experienced eye and nose irritation and headache. The supervisor of maintenance for the Metropolitan Sewer District notified the City Health Department and NIOSH. City health officials immediately closed the repair site, pending further investigation.

IV. METHODS AND MATERIALS

A. Environmental

1. February 23, 1981:

NIOSH industrial hygienists used direct-reading instruments to measure concentrations of explosive gases (J & W SSP) and of chlorine (Drager colorimetric tubes) in the sewer work area, and with appropriate protective equipment, descended 18 feet into the first level of the vertical sewer shaft to conduct organic vapor testing and to collect bulk samples of industrial effluent. Except for physical entry, the sampling procedure was repeated at three other sites along a sewer conduit upstream from the work site.

On February 25, 1981, NIOSH contacted all industries connected to the sewer line where environmental samples were collected. The purpose was to check if these industries may have contributed to the wastewater contaminants that caused illness among the sewer workers on February 22, 1981. MSD blueprints showed a gas station, a steel castings company, a brass and bronze ingot manufacturing company, and soap manufacturing company, to have sewer lines connected to the main sewer line leading to the sewer worksite. Results from the NIOSH telephone survey of these companies showed the gas station and two of three industries closed on February 22, 1981. The one industry (soap manufacture) did not use chemicals unrelated to what was found in solvents found in worksite samples. In addition, these sewer lines are no longer used by the soap manufacturing company. Finally, a large pigment plant used various organic solvents and acids in their manufacturing operations.

Five charcoal tube samples, 1 blank charcoal tube, and 28 bulk wastewater samples collected on February 22 and 23, 1981, were submitted for analysis of organics. Sample #1 was collected at the work site while the remaining charcoal tube samples for organics in sewer vapor spaces were collected at other sites. Pump flow rates were 0.2 liters per minute (LPM) or 1.0, lpm, and air collection times ranged from 70 to 90 minutes.

Charcoal Tube Analysis: All of the charcoal tube samples were desorbed in 1 ml of carbon disulfide and analyzed by gas chromatography (FID) using a 12-foot, 20%, SP-2100/0.1% carbowax 1500 column. Samples 1, 2, 3, and 5 were also analyzed by Gas Chromotograph/Mass Spectrometer (GC/MS) for identification.

Wastewater Analysis: Of the 28 bulk water samples submitted, four 10-15 ml aliquots were extracted with 1-2 ml carbon disulfide as a means of determining any gross organic contamination. Analyses for organics were performed using a 25-meter methyl silicone capillary column. The pH was measured for all effluent samples using an Instrument Laboratories Electrometer (Model 245).

2. March 2, 3, and 23, 1981:

At the request of the MSD management, the NIOSH investigation was expanded to include medical examinations and tests for all MSD employees with significant symptoms involved in the sewer repair project (both before and after the six workers were exposed on February 22, 1981). On March 2, 1981, at the request of the pigments manufacturing plant, environmental sampling for contaminants was extended north and south of the plant to identify other possible sources of acid effluent and organic vapor. On March 3, 1981, while the pigments manufacturing plant ceased operations, five more environmental samples for organic vapors were taken in sewer workspaces.

On March 23, 1981, at the request of MSD, NIOSH was requested to: 1) evaluate the work site at Spring Grove Avenue for safe worker re-entry to evaluate sewer damage, 2) evaluate ventilation controls using an air compressor, safety equipment, and work practices for repair of the sewer, and 3) monitor the work area for environmental contaminants to test effectiveness of workplace controls.

During these sampling dates, NIOSH collected 24 environmental air samples in the vapor spaces of sewer conduits along Spring Grove Avenue, Chickering Street, Kings Run Road, and Sun Street. Sampling times ranged from 15 minutes to 90 minutes, and sampling pump rates ranged from 100 cc/min to 1.0 lpm. In addition, five short-term time-weighted average personal samples for organic vapors were collected on March 23, 1981, at the sewer repair site to determine vapor exposure effectiveness of forced-air ventilation as recommended by NIOSH. Sampling times ranged from 16-20 minutes, and pump rates from 100 cc/min to 1.5 lpm. To capture organic vapors, charcoal tubes were used with air sampling pumps calibrated at 0.1 lpm, and 1-2 lpm. A gas chromatograph and mass spectrometer were used to identify and quantitate the organic vapors. See Figure 1 for cross-section schematic of sewer worksite, and figures 2 and 3 for all sewer sampling points.

B. Medical

The NIOSH medical investigation was performed in four stages: 1) on-site medical interviews with exposed sewer workers, February 23, 1981; 2) phone interviews with exposed sewer maintenance workers, February 23-March 3, 1981; 3) NIOSH/City of Cincinnati Employee Health Service Surveillance Program, March 1-present; and 4) follow-up medical questionnaire and liver function evaluation, March 18, 1981.

1. The first stage, performed at the sewer excavation site simultaneous with the environmental investigation on February 23, 1981, involved interviews with workers exposed on February 22nd who had complained of symptoms. The NIOSH medical officer used a brief questionnaire to elicit the workers' history of past medical problems, social history, symptoms, and occupational history.

2. The second stage was undertaken immediately to determine possible health effects of all those exposed to the site. The MSD agreed to provide the names of all MSD employees who had been exposed to the excavation site for 1/2 hour or greater anytime since the discovery of the cave-in on February 17. Workers were called by phone either at home or at work and asked to respond to the same questionnaire used in the initial stage. Those who had symptoms suggestive of the most severe acute solvent intoxication, or irritation of the mucous membranes or the chest, were referred to the Employee Health Service, City of Cincinnati (EHS) for further work-up and ongoing surveillance.

3. The NIOSH/City of Cincinnati EHS surveillance program was undertaken on March 1, 1981. Included in this clinical evaluation and follow-up were history and physical examination, laboratory examination including

complete blood count, liver enzymes, total protein, albumin, bilirubin, glucose, blood urea nitrogen, creatinine, cholesterol, triglycerides, serum iron, calcium, phosphorus, uric acid, electrolytes, urinalysis, and chest X-ray, if clinically indicated. A sample of each serum collected was spun and frozen for subsequent analysis by a NIOSH contract clinical laboratory. The evaluation was repeated weekly for the first 3-4 weeks following exposure, then as indicated for those with continuing abnormal blood tests or symptoms.

4. A follow-up survey was performed by a NIOSH medical team on March 18, 1981, at MSD headquarters. Interviewers used the same questionnaire as in the first and second phases, with the addition of questions about alcohol use. A blood sample was drawn for liver function evaluation, and performed within 24 hours by a NIOSH contract clinical laboratory. A control group of non-exposed MSD Sewer Maintenance Division workers was selected from a list provided by Dr. Scott Clark, Principal Investigator on an EPA Study of Health Effects of Exposure to Wastewater. This study was a 3-year longitudinal study of potential biological health risks of human exposure to wastewater in Chicago, Cincinnati, and Memphis, and involved approximately 60 of the Cincinnati MSD sewer maintenance workers. Results of that study showed that experienced Cincinnati sewer maintenance workers had a statistically significant correlation between several liver function tests and age and race. Therefore, our non-exposed study controls were selected, matched for age 5 years, and race with the surveillance group (stage 3).

V. EVALUATION CRITERIA

Exposure criteria have been developed to evaluate worker exposure to toxic substances in an occupational setting. Based on available human and animal studies, and industrial experience, these values represent levels to which nearly all workers may be exposed for an 8-hour day, 40-hour work week, throughout a lifetime without adverse effects. The toxic effects of the solvents identified by NIOSH at the worksite have been previously reported to include:

1. Skin irritation and irritant dermatitis due to defatting of skin.

2. Irritation of the mucous membranes, including eye, nose, and throat irritation.

3. Irritation of the lower respiratory tract and lungs, leading to chemical pneumonitis if dose is high enough or exposure is prolonged enough.

4. Neurobehavioral effects, including nausea, vomiting, dizziness, memory impairment, and loss of coordination.

The systemic effects of solvent exposure include the hematologic system (pancytopenia, anemia, leukemia), and liver and kidney injury. Carcinogenicity has been tested in 5 of the 7 solvent compounds found at the worksite. Three of the chemical solvents identified (tetrachloroethylene, trichloroethylene, and benzene), are known animal or human carcinogens.

Table I (Sections A and B) summarizes the chemicals of concern in this hazard evaluation, the recommended exposure criteria (where available), and comments on known health effects of each substance.

RESULTS

A. Environmental

1. February 23, 1981:

Volatile Organics: Direct-reading instruments indicated the presence of volatile organic substances (200-600 ppm) at the sewer repair site (direct reading instrument J&W SSP, calibrated for n-hexane). Qualitative analyses of sewer air samples taken at the same time using charcoal tubes, indicated the presence of several solvent compounds, including mineral spirits, 1,1,1-trichloroethane, trichloroethylene, toluene, perchloroethylene, xylene, and chlorobenzene. Initial quantitative analyses showed concentrations of mineral spirits of 517 ppm (2114 mg/M^3) in the sewer vapor space next to the pigment manufacturing plant, and of 20 ppm in a sewer approximately 200 yards above the plant. These concentrations may represent minimum concentrations since there was breakthrough of solvents on all but one sample, which was taken above the plant. Quantitative results for these compounds are in Table II.

Wastewater Analysis: No organics were detected in the 28 initial bulk samples by gas chromatography (FID) in any of the carbon disulfide extracts and, as a result, no other bulk wastewater samples were extracted. The pH of those samples taken from the sewer repair site ranged from 1.7 to 10.7. The pH varied as the effluent color changed. The bluish effluent had an acidic pH (range 1.0-3.0). Effluents of other colors (orange-yellow) generally had higher pHs. Samples were also taken from the main sewer line near the two wastewater discharge pipes of a nearby organic pigment manufacturing plant located along the main sewer line approximately 500 yards upstream from the sewer repair site. The samples taken near the discharge pipe for the blue pigment (phthalocyanine) wastewater had a pH ranging from 1.0-7.0. Samples taken near the discharge pipe for the red-orange pigment (azo) ranged from 8.0-9.4. The pH of the two samples taken upstream above the plant (sample site #5) were 7.3 and 8.5 (Table IIIa). Chloride ion concentrations were also higher in the effluent at the repair site (8,000-24,000 ppm) than at the sampling site above the pigment plant (150-1,500 ppm) (Table IIIb). As a reference, tap water from NIOSH laboratory facilities contained approximately 40-50 ppm chloride ion.

Site Visit - Organic Pigments Manufacturing Plant: The pigment manufacturing plant was visited by the NIOSH investigators. The plant uses large amounts of solvent hydrochloric acid, and sulfuric acid in its manufacturing processes. Although the company has a procedure to neutralize this acid by adding caustic soda to a holding tank before effluent is discharged, pH and chloride ion measurements taken by NIOSH and the city sewer department indicated that large amounts of unneutralized effluents were frequently discharged by the plant into the sewer line. No other source of acid discharge could be identified in the area. Further investigation at the plant revealed that the firm's pH-monitoring equipment was inoperative.

2. March 2, 3, and 23, 1981:

Nine chemical contaminants were identified in sewer samples taken in the worksite area: 1,1,1-trichloroethane, trichloroethylene, toluene, perchloroethylene, xylene, aliphatic naphtha mineral spirits, aromatic naphtha, trichlorobenzene, and benzene. Environmental mapping confirmed the source of the first six contaminants to be from the pigments plant. However, aromatic naphtha, trichlorobenzene, and benzene appear to originate from other industrial sources.

The predominant contaminant was mineral spirits. One sample showed a concentration of 6700 milligrams per cubic meter (mg/M^3) in a sewer next to the pigments plant.

The NIOSH-recommended standard for mineral spirits is 350 mg/M^3. 1,1,1-trichloroethane (commonly called methylchloroform) was the next major contaminant, with a concentration of 981 mg/M^3 in one sewer sample. Benzene was found at 31.6 mg/M^3 to the south of the pigments plant, and, to the north, trichlorobenzene was as high as 108 mg/M^3.

Two personal breathing air samples were collected on March 3, 1981, from workers in a sewer box tunnel connected to a sewer line leading to the pigments plant. The results showed exposure to mineral spirits (610 mg/M^3 and 370 mg/M^3); 1,1,1-trichloroethane (530 mg/M^3 and 260 mg/M^3); and trichloroethylene (110 mg/M^3 and 56 mg/M^3). Both workers were wearing organic vapor/acid gas respirators, and the pigments plant ceased production and had been flushing its sewer line with water. The solvent exposure may have occurred when a sandbag barricade was broken by the workers in the box tunnel, releasing a pocket of organic vapors. The two workers quickly climbed out of the sewer work area and began to ventilate this space with a forced-air fan. Medical tests were conducted on these workers the next day. Sampling results and locations are in Table IV.

On March 23, 1981, five personal samples were collected for organic contaminants at the Spring Grove work site. Results are shown in Table V. NIOSH, MSD, and MSD contractor personnel entered the work area (40 feet below street level) with respiratory protection (half-face respirator with organic vapor cartridges), and an organic vapor monitor (J & W SSP), to survey the sewer damage. An air compressor and jet exhaust venturi blower were used to ventilate the work area. Environmental results showed two compounds: trichloroethane and trichlorobenzene, which ranged from non-detectable to 0.6 mg/M^3 for trichloroethane, and non-detectable to 1.5 mg/M^3 for trichlorobenzene.

Ventilation measurements taken with an air velometer measured between 100-200 feet per minute (fpm) of air being pushed into the sewer workspace. The air compressor can supply 190 cubic feet of fresh air per minute. However, MSD has a larger air compressor capable of pumping 250 cfm, if needed.

B. Medical

1. Case Reports:

Five of the most severely affected workers were interviewed at the site of the cave-in excavation on the afternoon of February 23, approximately 24 hours after the site was closed by the superintendent of sewers. Their ages ranged from 23-46 years. One had a history of diabetes mellitus, another had a history of chronic bronchitis. Three had already been seen by physicians from the EHS who had performed a history and physical examination. Symptoms reported in order of frequency were eye and nose irritation, headache, dizziness, chest discomfort, shortness of breath, and vomiting, occurring within 45 minutes of the start of work on February 22. All complained of odors "like cleaning fluid" or "paint thinner," and a persistent metallic taste in the mouth. One worker had worked a total of 3 days at the site as a backhoe operator, and developed symptoms only after a brief exposure on February 22. Another worker, an inspector, had been at the site for varying periods daily from February 17, and had no complaints at the time of the initial interview.

2. Cross-sectional Study:

A total of 201 workers are employed by the Sewer Maintenance Division of the MSD. Of these, 46 were exposed to the sewer cave-in site for more than 1/2 hour during the period from February 17-March 3, 1981. All 46 of the exposed workers, and 17 of the 18 selected unexposed controls agreed to participate. The total exposed group was not significantly different from the control group in age, race, smoking status, length of employment, or alcohol intake (Table VI).

Nausea, headache, dizziness and throat irritation were all significantly increased in prevalence in the exposed compared with unexposed controls (Table VIIa). When individual symptoms are grouped into symptom syndromes, 28 (61%) of the exposed group had a case of mucous membrane irritation (eye, nose, or throat irritation), 27 (59%) had systemic symptoms (nausea, headache, vomiting, or dizziness), 15 (37%) had chest symptoms (cough, chest tightness, wheezing, chest pain, or shortness of breath), and 7 (15%) had a case of acute bronchitis (cough with sputum production). When exposed workers are compared with unexposed controls, a significant difference is found in the number of exposed workers with two or more symptom syndromes reported (odds ratio = 5.32, $p = 0.0056$) (Table VIIb).

The onset of symptoms was reported most frequently on two days: February 18 (the first day of actual excavation), and February 22 (the first day after reaching the level of the 18-inch main pipe from Kings Run Avenue) (Figure 4).

3. Results of Surveillance Program:

Clinical Evaluation: The 17 workers who were followed in the surveillance program were evaluated clinically by physicians employed by the EHS for signs

of solvent effects on the mucous membranes, chest, and neurological systems in particular. Two workers had neurological abnormalities and were referred for further medical evaluation. Results of this evaluation showed one worker was found to have highly elevated values of liver enzymes on NIOSH's follow-up examination 3 weeks following exposure, and had continued symptoms of headache, dizziness, memory difficulties "blackouts", and eye and skin irritation. He had a history of alcohol intake of a six-pack of beer per week, and prior episodes of intoxication with unknown toxic substances while at work on a sewer at a site close to this worksite (Spring Grove Avenue) one year prior to present episode. This worker was subsequently hospitalized where a blood ammonia level was found to be 268 (normal range 0-75) but EEG's and CT scan of the brain were normal. His discharge diagnosis was hepatic encepalopathy. The worker continued to complain of symptoms, and was referred to a psychologist for evaluation of possible psychological sequelae. This worker was given persmission to return to work on light duty by his physician.

Hematological Evaluation: To monitor exposed workers for possible hematologic complications of solvent exposure, weekly complete blood counts were performed on the 17 workers in the surveillance program. The red blood cell count, hemoglobin, platelet count, white blood cell count, differential white blood cell count, and red blood cell indices all were normal. The mean hematocrit, however, dropped slightly between week 1 and week 3, and the red blood cell count also showed a small drop. Nine workers had a hematocrit less than the normal range of 42-52%, and six workers also had an elevated reticulocyte count (an index of new red blood cell production and release from the blood-forming organs into the blood). The mean hematocrit for week 3 was 41.7% (normal 42-52%) and the mean reticulocyte count on week 2 was 1.9% (normal 0.5-1.5%) (Table VIII).

Liver Function Evaluation: Eight cases of elevations above the normal range in two or more liver enzymes were found among exposed MSD workers. No such cases were found among controls. No significant time trend, or elevation in mean liver enzyme levels were noted when exposed MSD workers were compared with unexposed controls (Table IX). A rise in mean serum total bilirubin was noted between weeks 1 and 3 among exposed workers (Table X). This difference disappeared, however, when exposed workers were simultaneously compared to unexposed controls, suggesting that this was due to laboratory or sample collection variation.

4. Case Control Analysis:

A case control analysis was then performed to attempt to define potential risk factors for adverse health effects, defined as a sewer maintenance worker who experienced any one or more of the following:

1. Two or more symptom syndromes;

2. Two or more liver function abnormalities;

3. Evidence of hematologic abnormality (hematocrit less than normal combined with elevated reticulocyte count).

Hypothesized risk factors included:

a. Work on particular days:

To evaluate the first hypothesis that work on certain days might lead to a higher risk of developing a case of adverse health effect, prevalence of cases (by date of onset of symptoms) were compared. February 18 and February 22 both had significantly higher prevalence rates (52% and 60%, respectively) compared with all other days combined (Table XI).

b. Location of actual work:

To evaluate the effect of location of actual work, workers were separated into "top" and "bottom" workers based on a history of work only on top of the excavation site, or having worked any amount of time at the bottom of the site. No significant excess risk of location of actual work was noted for adverse health effects (Table XII).

c. Job Category:

When analyzed by job category, laborers had no increased risk of sewer worker illness when compared with other job titles (Table XIII).

d. Length of Actual Exposure:

No relationship was found in terms of duration of total exposure (expressed as total amount of time worked at the job site) when workers who spent less than 8 hours at the site were compared with workers who spent more than 8 hours (Table XIVa).

e. Length of Employment:

No relationship was found for total length of employment (Table XIVb).

The results of the medical evaluation may be summarized as follows:

1. Forty-six workers were exposed to the sewer cave-in site between February 17 and March 3, 1981.

2. Thirty-one of these exposed workers had adverse health effects: 27 who were symptomatic; and/or 8 with liver function abnormalities, and/or 6 with hematologic abnormalities.

3. Twenty-eight (61%) had symptoms of mucous membrane irritation, 27 (59%) had symptoms of systemic effects, 15 (33%) had chest symptoms, and 7 (15%) had symptoms of acute bronchitis.

4. Exposed sewer maintenance workers had a significantly greater risk of developing adverse health effects compared with non-exposed controls.

5. Significant risk factors for development of adverse health effects included work at the site on either February 18 or February 22, 1981.

VII. DISCUSSION

These results suggest an acute episode of solvent intoxication producing symptoms and signs consistent with the known effects of the solvents found in NIOSH environmental monitoring of the cave-in site (Table I). The mixture of various solvent may have had either an additive or synergistic effect to produce the spectrum of symptoms and signs reported.

The hematologic test results are of concern. Evidence of anemia was observed in more than 50% of the workers in the NIOSH/EHS surveillance group. No simultaneous control values were obtained. The possibility of chronically low hematocrit values is suggested by the previously reported values for mean hematocrit in the EPA University of Cincinnati study among MSD employees showing a value in the lower part of the normal range (42-44 in 1976), with a significant difference among the various exposed and unexposed groups. Possible explanations for the 6 workers with anemia and reticulocytosis include (1) Systemic lab error - but EHS changed labs after the first results were seen, and comparable abnormal values were obtained on weeks 2 and 3; (2) Hemolytic anemia - classically presents as an anemia with reticulocytosis. The rise in mean bilirubin during the surveillance period is also suggestive, but a similar higher value was found in the control group. Why this hemolysis would occur several weeks after the exposure had ceased is not clear. Also not explained is the reason why the hematocrits failed to return to normal after a clear reticulocytosis had resolved. No serum haptoglobin or other more definitive diagnostic test was performed.

The transient and persistent (up to 3-4 weeks past exposure) liver function test abnormalities in eight of the exposed workers suggests acute liver toxicity due to exposure to the solvents at the work site. Potential confounding factors for the interpretation of these liver function abnormalities include: (1) acute infectious hepatitis - but only 1 case of type A viral hepatitis was found in the 3-year surveillance of all the sewer workers in the EPA study, and no cases of type B viral hepatitis. (2) alcohol ingestion - but no significant difference was noted in overall alcohol intake among the exposed vs. the control groups. No history of recent alcohol intake was obtained, however, and it is possible that acute ingestion of alcohol may explain the differences seen, although such a selective difference between the exposed and control groups would be unlikely.

The identification of work on particular days (February 18 and 22) as risk factors for developing sewer worker illness, and the lack of evident association with location of work, job title, or duration of exposure may reflect the highly variable and intermittently high exposures which may have led to the development of the illness.

Sewer workers may be exposed to myriad chemical contaminants while working in industrial areas. Wastewater effluents from many different industries commonly channel into sewer conduits and, if not properly pre-treated, may react to form hazardous contaminants and unhealthy conditions not only for sewer workers, but also for the general public.[1]

In this incident, the sewer collapse was apparently caused by erosion of concrete sewer pipe by chemicals discharged into the sewer system over a period of time. The sudden onset of symptoms in the sewer workers appears to have resulted from their exposure to the vapors of organic effluent which accumulated in the vapor space above the wastewater.

Protection of sewer workers from future incidents such as this one will involve vigorous enforcement of wastewater regulations, adequate industrial hygiene measurement of potentially dangerous sewer atmospheres prior to sewer entry, provision of proper sewer ventilation, proper use of adequate personal protective equipment while working in or near sewers, and adequate medical surveillance to enable early detection of illness associated with exposure to toxic chemicals in the sewer environment.

RECOMMENDATIONS

Recommendations below are intended to aid the MSD in preventing occupational health problems in its future operations.

1. Instrumentation and Training:

   a. Before entering the sewers, MSD personnel should test the atmosphere with rugged, portable, direct-reading instruments such as explosimeters, oxygen detectors, and supplemented if appropriate by organic vapor detectors, and colorimetric indicator tubes.

   b. Training of MSD personnel in the use of direct-reading instruments should be conducted before MSD personnel use equipment at a work site.

2. Respiratory Protection:

   a. Because of the chemical composition of the sewer's atmosphere and its potential to change rapidly and without notice, particularly in the industrial section which receives both commercial and industrial sewage, the underground personnel should use open-circuit air-line supplied respirators when direct-reading instruments indicate the presence of toxic substances in concentrations immediately dangerous to health or life. At lower concentrations, NIOSH-approved full- or half-face chemical cartridge respirators should be worn by personnel entering industrial sewers.

   b. A respiratory protection program meeting the requirements of 29 CFR 1910.134 should be established and enforced by MSD management. The NIOSH publication titled "A Guide to Industrial Respiratory Protection," will serve as a reference source for establishing and maintaining a respiratory protection program.

3. Engineering Controls:

   a. Forced-air ventilation should be used whenever possible when working in sewers, especially industrial sewers.

   b. The jet exhaust venturi blower (air horn) connected to the end of the compressor air hose (with organic filter) and used to aspirate fresh air into the workspace should be kept at street level. The air intake should be away from automobile or diesel exhaust emissions. A flexible elephant duct should be attached to the blower and extended to the work area to bring fresh air from the surface.

4. Medical Surveillance:

   Employee Health Service, City of Cincinnati, should develop a system for reporting symptoms following exposure to chemical contaminants in sewers. A log of such reports should be maintained. In combination with results of such medical tests as deemed necessary, such a log will enable MSD and its medical consultant to determine any adverse trends in exposure incidents.

5. Safety:

   a. The city safety program should be strengthened, and should have industrial hygiene support.

   b. Each underground worker should be provided with arm wristlets, safety lines, and harnesses for rapid removal from the sewer.

6. Other:

   a. The City Fire Department's Emergency Response Team should be alerted whenever MSD workers are entering a sewer environment that may be hazardous to the worker. Contact with the fire department closest to the work area may be sufficient.

   b. When the source of the chemical contaminant(s) in sewers is known, and MSD personnel are working downstream from this source, MSD authorities should contact the Company and tell them to hold their discharge until survey or sewer repairs are completed.

   c. Sewer permits for industrial workers should include liquid waste compounds, and potentially volatile compounds which may be present in sewer vapor spaces after discharge.

IX. REFERENCES

1. Kominsky, J.R., C.L. Wisseman, D. Morse, et al. "Hexachlorocyclopentadiene Contamination of a Municipal Wastewater Treatment Plant," American Industrial Hygiene Association Journal, Vol. 41: 552-56, 1980.

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X. DISTRIBUTION AND AVAILABILITY OF REPORT

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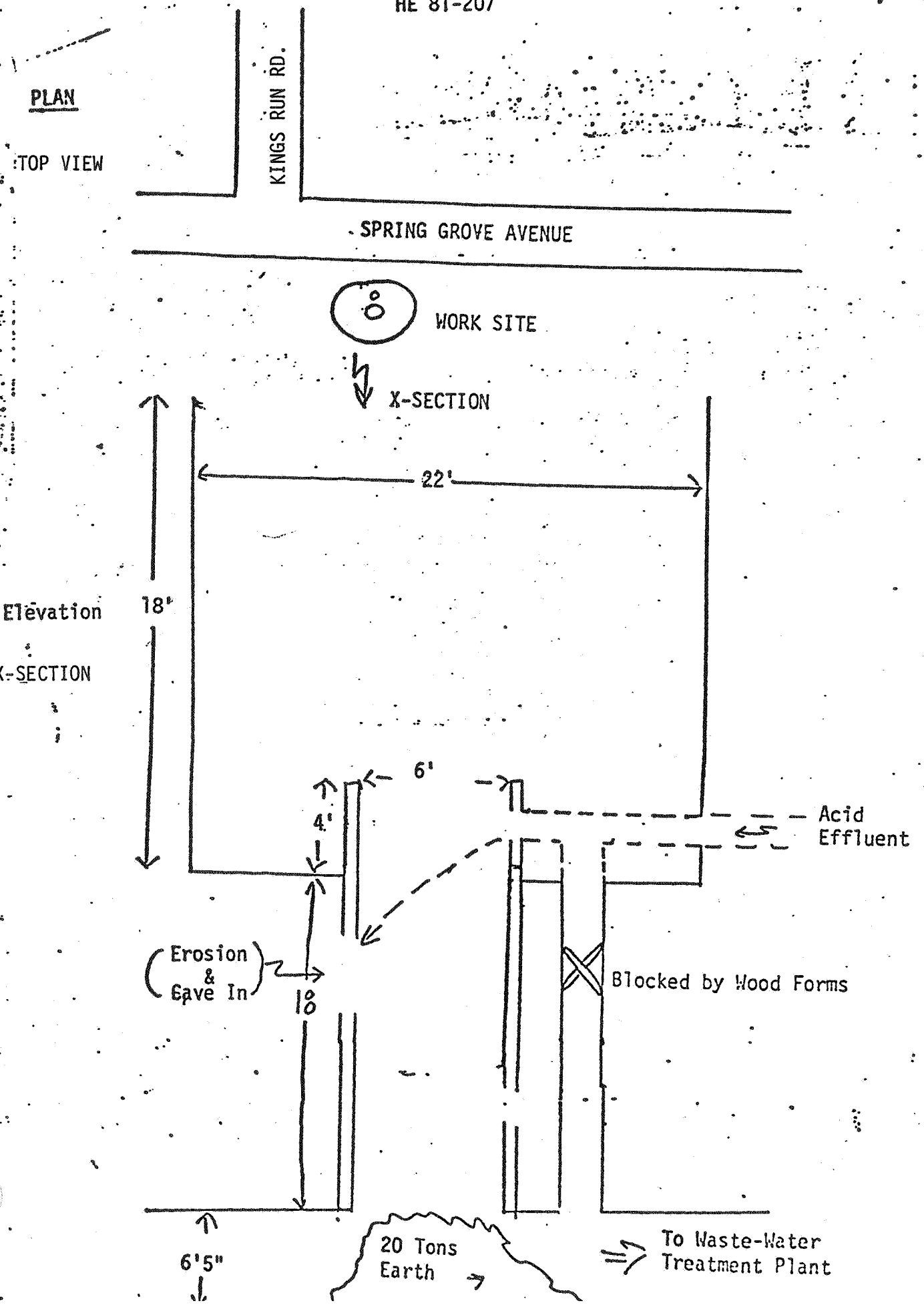
Copies of this report have been sent to:

1. City Health Commissioner
2. Director, City Maintenance
3. Superintendent, MSD
4. Cincinnati City Solicitor
5. Cincinnati City Prosecutor
6. Cincinnati Law and Safety Committee
7. Mayor, City of Cincinnati
8. Sun Chemical Company
9. NIOSH, Region V
10. OSHA, Region V

For the purpose of informing the "affected employees," the employer shall promptly post, for a period of 30 calendar days, this report in a prominent place(s) where the exposed employees work.

FIGURE 1

Metropolitan Sewer District
Cincinnati, Ohio
HE 81-207



Metropolitan Sewer District
Cincinnati, Ohio
HE 81-207

FIGURE 2

● KEY SAMPLING SITES

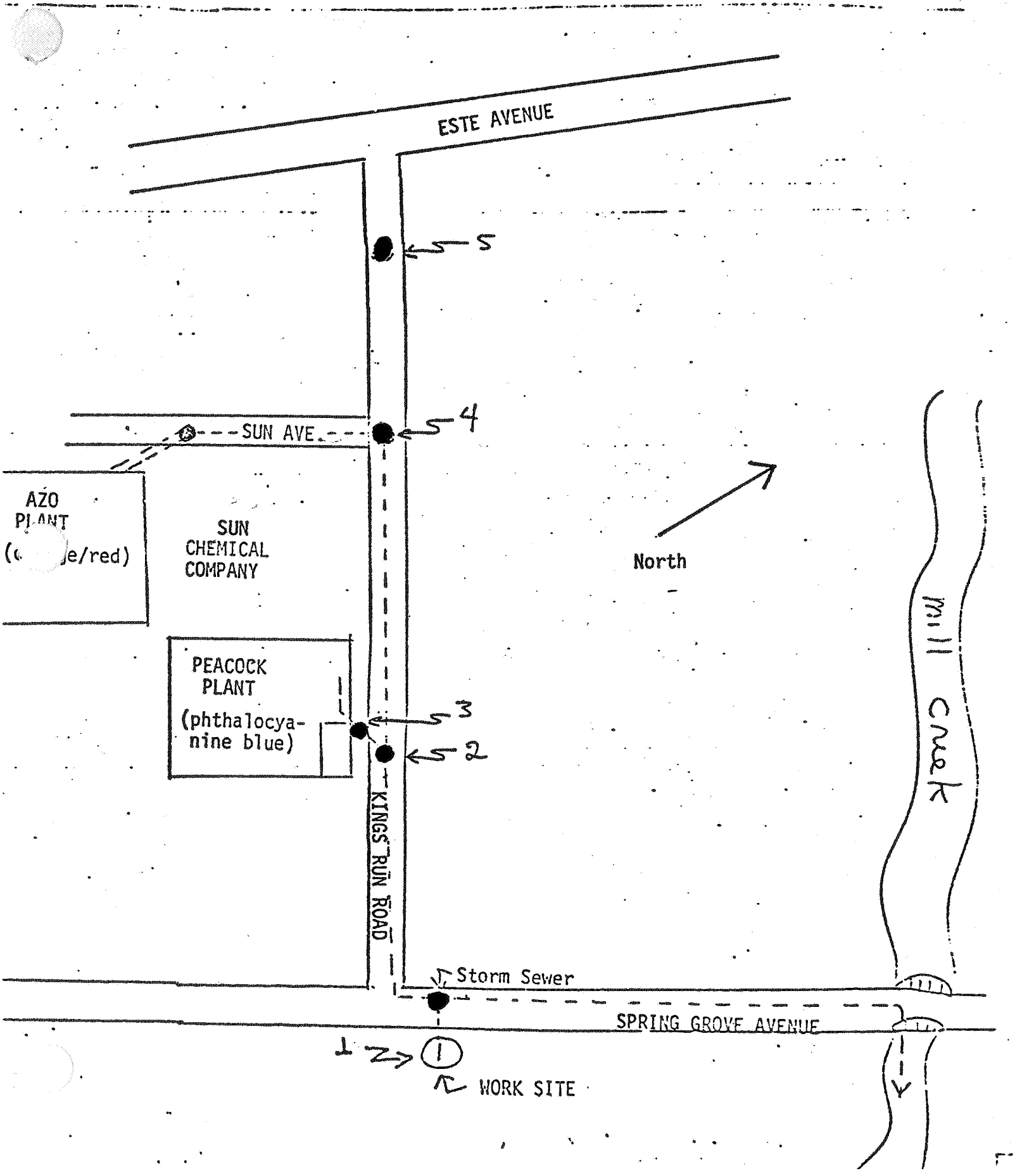


FIGURE
Metropolitan S[illegible] District
Cincinnati, Ohio
HETA 81-207

KEY: ● Sampling Sites

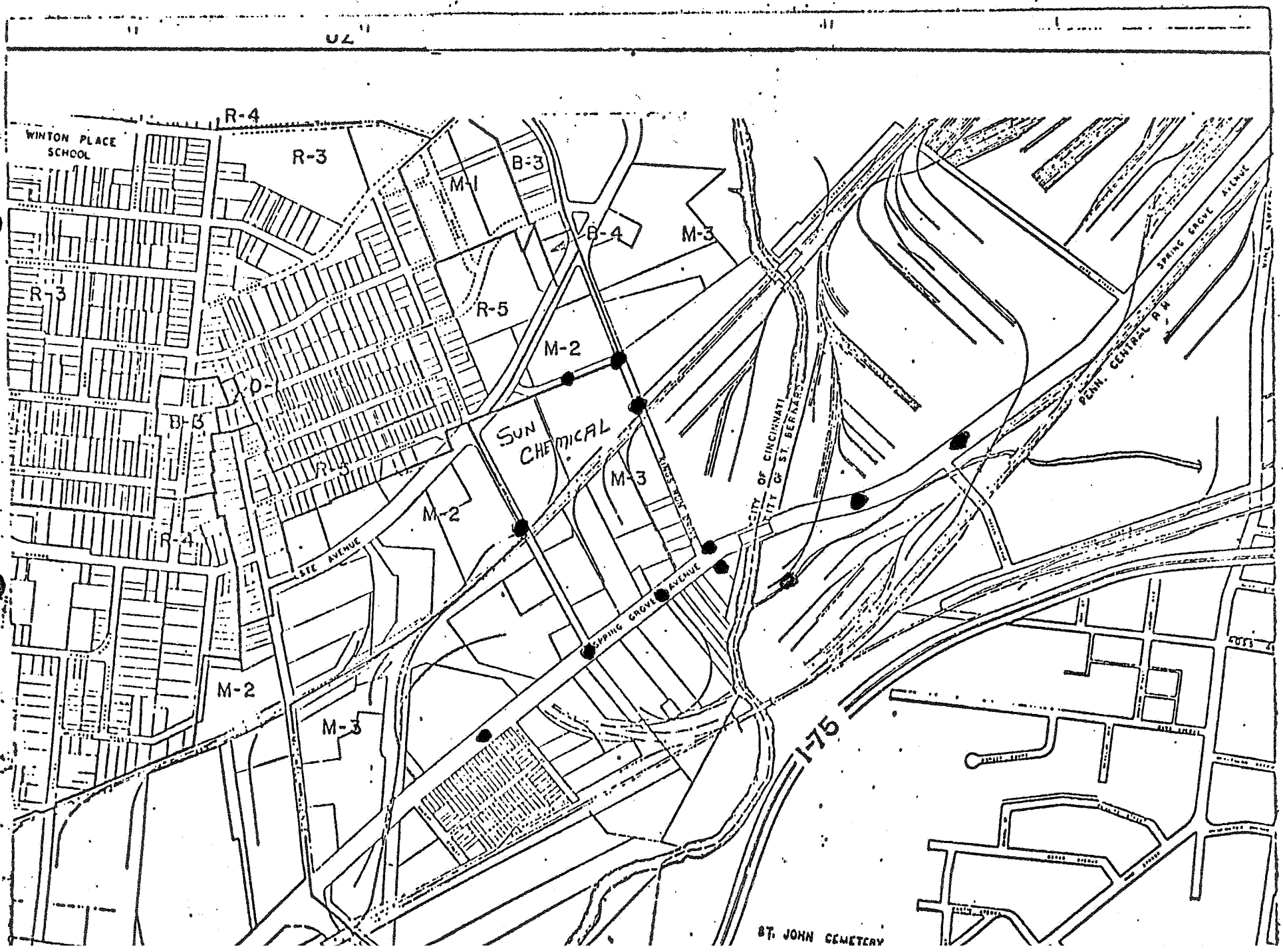


TABLE I (Sec)

Reported Effects of Solvent Exposure in
the Literature and Current Regulatory Status

Metropolitan Sewer District
Cincinnati, Ohio
HETA 81-207

Substance	EPA Priority Pollutant	Symptoms* Skin	MM	Ch	N	Systemic Effect Heme	Liver	Kidney	Cancer Testing
Chlorobenzene	+	+[a]	+[a]	-	+[a]	-	+[d]	+[d]	I.P.**[f]
Mineral Spirits*	-	+[c]	+[c]	+[b]	+[b]	+[c]	+[b]	+[b]	-
Tetrachloro-ethylene	+	-	+[b]	+[b]	+[b]	-	+[b]	+[b]	+[f]
1,1,1-trichloro-ethane	+	-	-	-	+[c]	-	+[c]	+[c]	-[f]
Trichloro-ethylene	+	-	-	-	+[b]	-	+[b]	+[b]	+[f]
Toluene	+[a]	-	+[a]	-	+[a]	-	+[c]	+[c]	I.P.[f]
Xylene	+[a]	-	+[a]	-	+[a]	+	-	-	-
Benzene	+								+[f]

+ = positive health effect - = no health effect
*MM = Mucous membrane irritant Ch = Chest irritant
N = Neuro-behavioral effects (including nausea, vomiting, dizziness, memory impairment, or loss of coordination.
**I.P. = In Progress

Reference Key:
a. Proctor & Hughes, Chemical Hazards in the Workplace, 1978.
b. Dreisbach, Handbook of Poisoning, 1967.
c. NIOSH Criteria Document on respective solvent.
d. Daugaard, Symptoms and Signs in Occupational Disease, 1978.
e. NIOSH/OSHA Pocket Guide to Hazards, 1980/
f. NIOSH, Registry of Toxic Effects of Chemical Substances (RTECS), 1979.

Table 1 (Section B)

Metropolitan Sewer District
Cincinnati, Ohio
HETA 81-207

Solvents Detected	M.W.	°F B.P.	V.P.	% UEL	% LEL	IDLH Level	°C Flash Point	(ppm) PEL	Health Effects
1,1,1-trichloroethane	133	165	100mm	16.0	7.0	500ppm	?	350ppm ceiling	Narcotic, and depresses the CNS. Irritating to eyes, and nose.
Trichloroethylene	131	188	58mm	41.0	11.0	1000ppm	---	100ppm OSHA 300 peak	Attacks the respiratory system, heart, liver, kidneys, CNS, and skin.
Toluene	92	231	22mm	7.1	1.3	2000ppm	4	200 OSHA 500 peak 100 NIOSH 200 peak	Depresses the CNS. Toxic to liver & kidneys. Irritating to skin.
Refined Petroleum Solvent (Total naphtha C_9-C_{14})	144	(302-392)	2mm	(?)	0.8	5000ppm	38-43	500ppm (2950 mg/M^3) 350 mg/M^3 NIOSH 1800 mg/M^3 15 min ceil.	Irritating to skin, eyes, and respiratory system. Depresses CNS.
Perchloroethylene (tetrachloroethylene)	166	250	14mm	Not Combustible		500ppm	(?)	100ppm OSHA 200 ceil. 50ppm TWA NIOSH 100ppm ceil.	Toxic to liver & kidneys. Irritating to eyes, and upper respiratory system. Depresses CNS.
Xylene	106	292	7mm	7.0	1.1	10,000ppm	17-25	100ppm OSHA 100ppm NIOSH 200ppm ceil.	Depresses CNS. Irritates eyes and skin. Toxic to GI track, blood, liver, and kidneys.
Chlorobenzene	113	270	8.8mm	7.1	1.3	2,400ppm	29	75ppm OSHA 75ppm (ACGIH)	Irritating to respiratory system, eyes, and skin. Depresses CNS. Toxic to liver.
Trichlorobenzene	225	415	--	--	--	--	84	--	Toxic by ingestion and inhalation. Tested as carcinogen.
Benzene	78	176	75mm	7.1	1.3	2,000ppm	25	10ppm OSHA NIOSH - 1ppm ceil.	Toxic to blood, CNS, skin, and bone marrow. Irritating to eyes and respiratory system. A carcinogen.
Aromatic hydrocarbons excluding benzene	92-132	110-217	.65-30mm	6.7	0.8-1.1	--	97-65	--	Irritating to skin, and lungs. Some aromatics may cause cancer.

Key:
MW = Molecular weight
VP = Vapor pressure
BP = Boiling point
VP = Vapor pressure
UEL = Upper explosive limit
LEL = Lower explosive limit
IDLH = Immediately dangerous to life and health
PEL = Permissible exposure limit

TABLE II

Summary of Air Contaminants Found in
Sewer Lines and Work Site
(Reported in parts per million)

Metropolitan Sewer District
Cincinnati, Ohio
HETA 81-207

February 23, 1981

Contaminants	Sampling Sites				
	1	2	3	4	5
1,1,1-Trichloro-ethane	1.0	20.	15.	40.	8.
Trichloro-ethylene	0.9	5.4	0.4	7.3	1.3
Toluene	1.0	0.8	0.2	0.3	N.D.
Mineral Spirits	25.	482.	76.	517.	20.
Perchloro-ethylene	0.4	1.6	1.0	0.3	N.D.
Xylene	0.9	3.5	0.4	3.5	N.D.
Chlorobenzene	0.2	N.D.	N.D.	N.D.	N.D.

NOTE: Environmental levels represent minimum values since all charcoal tubes except #5 had breakthrough of organic vapors.

TABLE IIIa

pH Levels of Wastewater Effluent
at Sampling Points 1, 2, 4, & 5
(See Fig. 2 for locations 1 through 5)

Metropolitan Sewer District
Cincinnati, Ohio
HETA 81-207

Date	Time	Location	pH*
2/21/81	12:25	1	5.91
2/21/81	12:15	2	10.71
2/21/81	12:41	4	9.38
2/21/81	13:00	5	
2/22/81	10:55	1	2.03
2/22/81	11:00	2	1.83
2/22/81	11:05	4	8.00
2/22/81	11:10	5	
2/22/81	12:35	1	2.11
2/22/81	13:25	1	2.95
2/22/81	13:42	1	2.07
2/22/81	13:45	1	2.08
2/22/81	14:10	Outlet Pipe	1.89
2/22/81	14:30	1	1.72
2/22/81	15:00	1	2.26
2/22/81	15:15	1	2.33
2/22/81	15:35	1	1.96
2/22/81	15:55	1	1.94

* pH levels confirmed by NIOSH on February 24, 1981.

TABLE IIIb

Chloride Ion Results for Wastewater Effluent
Collected at Sampling Points 1, 2, 4, & 5
(see Figure 2)

Metropolitan Sewer District
Cincinnati, Ohio
HETA 81-207

Date	Time	Location	Chloride Ion Concentration (ppm)*
2/22/81	10:55am	Worksite (1)	8,000
2/22/81	2:30pm	Worksite (1)	24,000**
2/22/81		Blue pigment discharge (2)	10,000
2/22/81		Orange/red pigment discharge (4)	5,500
2/22/81		Above pigment plant (5)	1,500
2/21/81		Orange/red discharge (4)	270
2/21/81		(5)	150
2/23/81	10:35am	(1)	8,000
2/23/81		(1)	7,000
2/23/81		(1)	1,600
2/23/81		NIOSH tap water (reference)	46

* ppm = parts per million
**Exceeds upper limit of detection of 24,000 ppm.

TABLE IV

Metropolitan Sewer District
Cincinnati, Ohio
HETA 81-207

Area Air Sampling Results in mg/M^3

March 2, 1981

Sewer Vapor Space Location	Time	Chloro-ethane	Trichloro-ethylene	Toluene	Perchloro-ethylene	Xylene	Total Aliphatic Naphtha	Total Aromatic Naphtha	Trichloro-Benzene
Worksite, bottom second sewer	5:26-5:28pm	N.D.	N.D.	8	12	N.D.	40	48	130
Worksite, first level	5:31-5:54pm	45	N.D.	15	20	5	100	55	120
P&G Ivorydale Pl Spring Grove Ave.	5:40-7:04pm	12	3.7	28	36	57	27	31	N.D.
Above P&G plant	5:52-7:05pm	N.D.	N.D.	N.D.	N.D.	N.D.	9.7	19	13
Worksite, first level	5:54-7:01pm	26	N.D.	9.6	6.4	16	74	130	103
Worksite, bottom second sewer	5:56-7:00pm	N.D.	N.D.	3.5	3.5	19	58	160	109
Manhole (A) Spring Grove Ave.	6:04-6:50pm	440	12	4.1	N.D.	N.D.	2100	N.D.	N.D.
Spring Grove Ave. Across from Snow Filtration Co.	6:10-7:09pm	N.D.	N.D.	140	N.D.	220	420	128	N.D.
Spring Grove & Chickering	6:15-7:10pm	N.D.	N.D.	1.8	N.D.	N.D.	N.D.	N.D.	N.D.
Chickering Ave. RR Tracks	6:24-7:15pm	N.D.	N.D.	1.9	N.D.	N.D.	N.D.	N.D.	N.D.
Kings Run & Sun Ave.	6:30-7:21pm	750	30	12	9.3	N.D.	6700	N.D.	N.D.
Sun Avenue	6:34-7:19pm	980	19	5.6	N.D.	8	1000	N.D.	N.D.
Kings Run RR Tracks	6:43-7:22pm	740	37	5.0	N.D.	17.	2700	N.D.	N.D.
Spring Grove between Chickering & Kings Run	6:55-7:35pm	5.0	N.D.	1.3	N.D.	N.D.	108	N.D.	N.D.

Benzene found at 0.18 mg/sample or 32.0 mg/M^3
Across from Snow Filtration Co., Spring Grove Ave.

TABLE IV Cont'd.

Metropolitan Sewer District
Cincinnati, Ohio
HETA 81-207

March 3, 1981

Location	Time	Chloro-ethane	Trichloro-ethylene	Toluene	Perchloro-ethylene	Xylene	Total Aliphatic Naphtha	Total Aromatic Naphtha	Trichloro-Benzene
Regulator chamber P&G Plant	9:52-10:55pm	N.D.	N.D.	1.5	N.D.	1.5	N.D.	N.D.	75
Personal, Sewer A Spring Grove	10:21-10:30pm	53	11	25.0	N.D.	N.D.	610	N.D.	N.D.
Personal, Sewer A Spring Grove	10:15-10:30pm	260	56	N.D.	N.D.	N.D.	370	N.D.	N.D.
Kings Run Excavation Site Connector Conduit for 18" to 60" line	10:26-11:13pm	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Kings Run Excavation Site Connector Conduit for 18" to 60" line	12:10-12:30pm	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

TABLE V

Personal Air Samples of Contaminants in Sewer
Work Site (40 ft. down) with Forced Air Ventilation

Metropolitan Sewer District
Cincinnati, Ohio
HETA 81-207

March 23, 1981

Time	Sample Volume (liters)	Flow Rate (lpm)	Contaminant in mg/M^3 1,1,1-Trichloroethane	Trichlorobenzene
1240-1305	30.5	1.20	0.6	0.66
1240-1349	42.2	0.61	0.6	0.90
1315-1322	0.28	0.01	N.D.	N.D.
1305-1315	0.20	0.01	N.D.	N.D.
1330-1349	23.2	1.20	0.43	1.5

N.D. = Non-detectable

TABLE VIa

HE 81-207
Metropolitan Sewer District, Cincinnati, OH

Table 1c
Flow diagram of NIOSH Medical Investigation

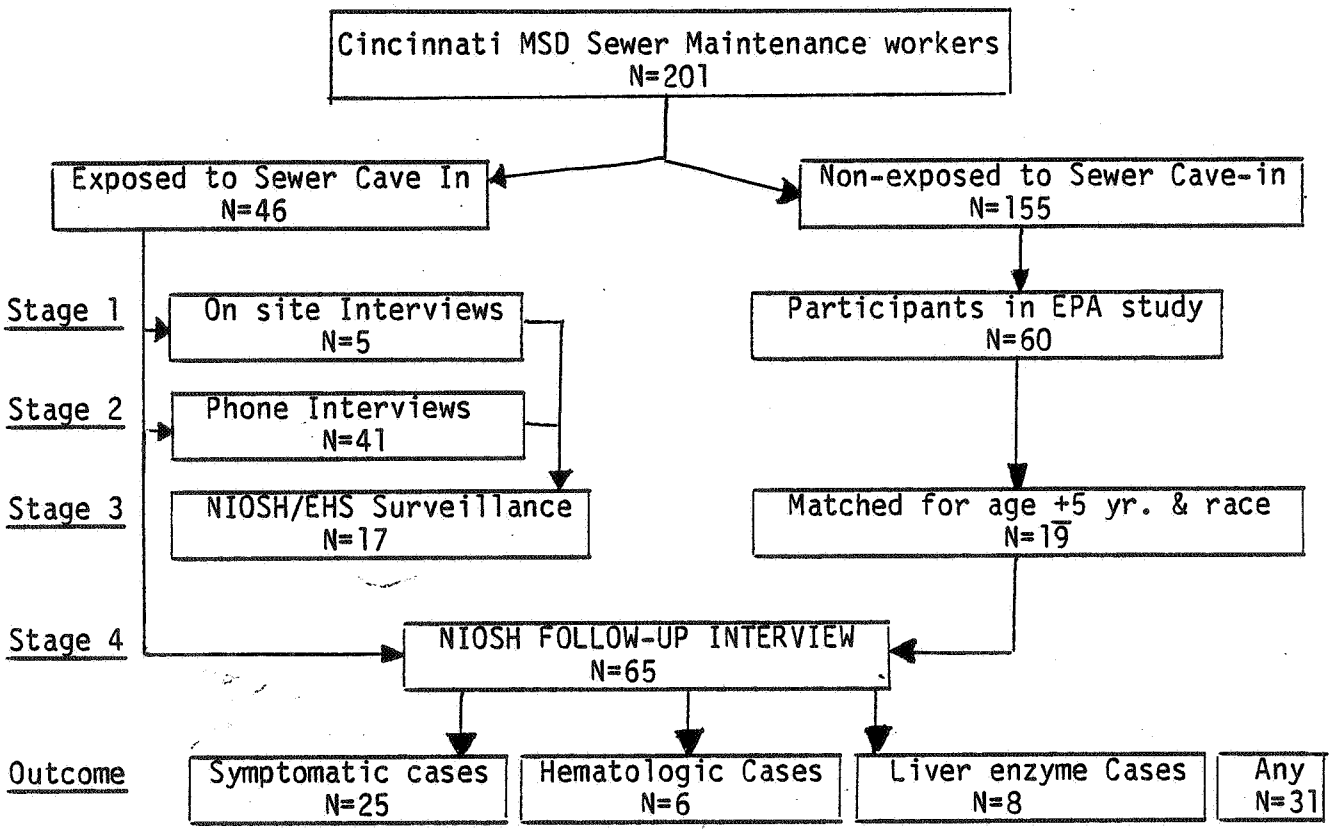


TABLE VIb

Comparability of Sample Populations

Metropolitan Sewer District
Cincinnati, Ohio
HETA 81-207

Characteristic	Exposed (n=46)	Unexposed (n=19)
Age: Range	20-61	27-64
Mean	36	37
Race: Black	21	12
White	21	6
Unknown	4	1
Past Medical History		
Hypertension	4	3
Diabetes Mellitus	2	0
Chronic Bronchitis	1	0
Heart Disease	2	0
Asthma	1	0
Cigarette Smoking		
Current Smoker	28 (61%)	7 (36%)
Past Smoker	8 (17%)	3 (15%)
Never Smoked	10 (22%)	8 (42%)
Unknown	0	1 (5%)
Alcohol Use		
Never Drink	3	7
Ever Drink	12	12
Length of Employment		
$\leq$1 Year	12	5
>1$\leq$5 Years	10	5
>5 Years	7	9

TABLE VIIa

Symptom Prevalence in Exposed and Unexposed
Control Sewer Maintenance Workers

Metropolitan Sewer District
Cincinnati, Ohio
HETA 81-207

Symptoms	Exposed (n=46)		Unexposed (n=19)		Significance Test (Fisher's Exact)
	#	%	#	%	
Nausea	13	28	1	5	p=0.035*
Headache	19	41	3	16	p=0.042*
Dizziness	16	35	1	5	p=0.011*
Eye Pain	19	41	5	26	p=0.197
Nose Irritation	13	28	2	11	p=0.108
Throat Irritation	16	35	2	11	p=0.041*
Skin Irritation	2	4	4	21	p=0.055
Chest Pain	8	17	3	16	p=0.594
Wheeze	5	11	2	11	p=0.669
Shortness of Breath	8	17	1	5	p=0.155

* Statistically significant at $p < 0.05$.

TABLE VIIb

Symptom Syndromes in Exposed vs. Unexposed
Sewer Maintenance Workers

Metropolitan Sewer District
Cincinnati, Ohio
HETA 81-207

	Exposed	Unexposed
Two or more symptom syndromes present:	27	4
Less than two symptom syndromes present:	19	15

Odds ratio 5.32, p=0.0056

TABLE VIII

Arithmetic Mean of Hematologic Results, Week 1-3

Test	Units	Normal	Wk. 1*	Wk. 2**	Wk. 3**	t[a]	df	p
RBC	10 /mm	4.5-6.3	4.95	4.86	4.75	1.17	27	0.25
HGB	g/dl	14-18	15.1	15.3	15.2	0.10	27	0.92
HCT	%	42-52	43.7	42.7	41.7	1.72	27	0.096
Plat.	10 /mm	150-400	"normal"	260	270	0.34	27	0.74
WBC	10 /mm	4.3-10	7.5	6.5	7.5	0.11	27	0.91
Retics	%	0.5-1.5	***	1.9	1.2	0.81	27	0.42

* Blood samples drawn and tests performed by EHS Contract clinical laboratory 1.
** Blood samples drawn and tests performed by EHS Contract laboratory 2.
a Comparing means of Week 1 and 3 except reticulocytes Week 2 and 3.
*** Not performed.

TABLE IX

Arithmetic Mean of Liver Function Tests, Follow-up Survey (Week 4) Exposed vs. Unexposed Sewer Maintenance Workers*

Metropolitan Sewer District
Cincinnati, Ohio
HETA 81-207

Test	Exposed (n=29)	Unexposed (n=17)	Test of Significance		
			t	d.f.	p
SGGT	39	35	0.49	44	0.63
SGOT	33	28	0.48	44	0.63
SGPT	29	31	0.31	44	0.76
Bilirubin (Total)	0.6	0.6	0.08	44	0.94

* All samples drawn and spun by NIOSH, performed by NIOSH contract clinical laboratory.

TABLE X

Arithmetic Mean of Liver Function Tests of Exposed Sewer Maintenance Workers*

Test	Units	Normal Range	Wk. 1	Wk. 4	Test of Significance t	df	p
SGGT	IU/L	0-65	37	39	0.16	42	0.87
SGOT	IU/L	0-42	22	33	0.86	41	0.39
SGPT	IU/L	0.45	33	29	0.42	42	0.68
LDH	IU/L	75-225	200	211	0.30	44	0.74
Bili-rubin (Total)	mg/dl	0-1.3	0.3	0.6	4.33	42	0.00009

* All tests performed by NIOSH contract clinical laboratory, specimens for week 1 drawn, spun and frozen by EHS, City of Cincinnati, specimens for week 4 drawn and spun by NIOSH.

Table XIa

Prevalence of Symptomatic Cases by Date of Onset

Metropolitan Sewer District
Cincinnati, Ohio
HETA 81-207

Date	Number Exposed	Number with Symptoms	Number with No Symptoms	Percent
2/17	12	2	10	17
2/18	23	12	11	52
2/19	8	2	6	25
2/20	13	3	10	23
2/21	7	2	5	28
2/22	10	6	4	60
2/23	8	2	6	25
2/24	5	0	5	0
2/25	4	1	3	25
2/26	4	0	4	0
2/27	3	0	3	0
2/28	2	0	2	0
3/1	2	0	2	0
3/2	5	2	3	40
3/3	2	1	1	50

TABLE XIb

Sewer Worker Illness
Person-days of Exposure - February 18 vs. Other Dates

Person-days of Exposure	Case	Non-Case
February 22	6	4
Other	27	71

Odds Ratio = 3.94 $X^2 = 4.5$, $p = 0.034$

(95% confidence interval: 1.35-11.48)

TABLE XII

Risk Factors
Location of Work vs. Sewer Worker Illness

Metropolitan Sewer District
Cincinnati, Ohio
HETA 81-207

Sewer Worker Illness	Location of Work	
	Bottom	Top
Case	14	16
Control	7	8

Odds Ratio = 1.0 X^2 = 0.0 p = 1.0

TABLE XIII

Risk Factors
Job Title vs. Sewer Worker Illness

Sewer Worker Illness	Job Title	
	Laborer	Other
Case	13	18
Control	7	8

Odds Ratio = 0.8 X^2 = 0.09 p = 0.76

TABLE XIVa

Risk Factors
Length of Exposure vs. Sewer Worker Illness

Metropolitan Sewer District
Cincinnati, Ohio
HETA 81-207

Sewer Worker Illness	Total Duration of Exposure	
	8 hours or more	less than 8 hours
Case	17	12
Control	6	9

Odds Ratio = 2.13 $X^2 = 1.37$ $p = 0.24$

(95% confidence interval: 0.72 - 6.20)

TABLE XIVb

Risk Factors
Length of Employment vs. Sewer Worker Illness

Sewer Worker Illness	Length of Employment	
	less than 5 years	more than 5 years
Case	22	7
Control	9	4

Odds Ratio = 1.4 $p = 0.46$

(95% confidence interval: 0.41 - 4.80)

TABLE XV

Participant Roster

Metropolitan Sewer District
Cincinnati, Ohio
HETA 81-207

#	SYMPTOMATIC CASE*	LIVER ENZYME CASE **	HEMATOLOGIC CASE ***	SURVEILLANCE PARTICIPANT
1	X		X	X
2	X			X
3	X	X		X
4	X	X		X
5	X		X	X
6	X			
7	X			
8	X	X		
9	X			
10	X			X
11	X			X
12	X			
13	X			
14	X			X
15	X			
16				
17				
18		X	X	X
19				
20	X			
21				
22		X		X
23				
24	X			
25	X	X	X	X
26			X	X
27				
28	X			
29	X		X	X
30				
31				
32				
33	X			X
34		X		
35	X	X		X
36	X			
37				
38				
39				
40	X			
41	X			X
42				
43				
44				
45				
46	X			

*=Two or more symptom syndromes
**=Two or more liver enzymes above normal range
***Hematocrit less than 42% and reticulocyte count greater than 1.5%