U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
CENTERS FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

TECHNICAL ASSISTANCE REPORT
~~TA-80-25~~ 80-0270-1061

Sioux Falls Water Reclamation Department
Sioux Falls, South Dakota

I. SUMMARY

On November 19, 1979, the National Institute for Occupational Safety and Health (NIOSH) received a request for technical assistance to evaluate complaints of excessive heart disease, respiratory weakness, and birth defects among the workers and families of workers employed at the wastewater treatment plant of the city of Sioux Falls, South Dakota. To confirm the reported cases and evaluate the treatment plant environment, a site visit and subsequent industrial hygiene survey were conducted.

No case-clusters of heart disease or birth defects could be confirmed and the size of the plant population was not suitable for a more extensive epidemiologic investigation. Area samples for determination of hydrogen sulfide and hydrocarbons were obtained.

Only hydrogen sulfide concentrations in the boiler room, near a pump in the degritter room, and at a manhole exceeded 20 ppm. The NIOSH recommended standard is 10 ppm for 10 minutes.

On January 30, 1980, NIOSH informed the union, plant manager, and the mayor and health officer of Sioux Falls that no imminent health hazard existed at the plant and that the health problems which had been confirmed were probably not caused by work at the plant. Based on the results of data obtained in this investigation, recommendations on ventilation, engineering controls, and work practices have been developed by NIOSH and are incorporated in detail on page 10.

INTRODUCTION

In November, 1979 the municipal employees of the Sioux Falls Wastewater Treatment Plant (SIC 4952) requested help from the city health officer, the plant management, the mayor, and Senator McGovern in order to ascertain whether there were hazards associated with their employment which might have caused "an inordinate number of deaths and impairments" among the employees and their families. South Dakota has no state OSH plan, but city officials requested NIOSH assistance on behalf of their employees who would otherwise not be eligible for a NIOSH HHE.

Specifically, the sewage treatment plant workers listed the following problems which were suspected to be associated with their workplace:

(1) "Respiratory weaknesses have occurred among several employees," characterized by prolongation or increased numbers of colds or sinus problems and seemingly worsened by "exposure to hydrogen sulfide and other toxins in digester gas and wastewater aerosols;"

(2) "In the last year, four workers have suffered serious heart disease. Two of these individuals are deceased and a third is still hospitalized. Their ages vary from 36 to 62. There are only 27 permanent full-time employees and many were hired only recently;"

(3) Of 8 pregnancies in the families of the employees within the past 2 years, 4 were abnormal--"one terminated in miscarriage, two infants died within days of delivery due to cogenital heart conditions, and the fourth has a serious birth defect (cerebral palsy)."

The purpose of the study was to review the history of alleged "cases" and evaluate the environment of the treatment plant for agents which might cause or exacerbate these health problems. To this end we conducted a site visit on January 2-5, 1980, and an environmental survey on July 25-26, 1980.

III. BACKGROUND

The present Sioux Falls secondary sewage treatment facility has been in operation since 1926. It occupies a 20-acre site on the outskirts of town next to a state penitentiary. The sludge lagoons occupy about 40-50 acres. An aeration system was added in 1934; a cascade-type aerator and an air-lift pump for the settling tank were added in 1970; and the chlorination system was added in 1972.

There have been no major changes in plant processes or upstream industries recently. The major industrial influents came from an abbatoir and a rendering plant. A tertiary treatment plant is under construction and will be phased-in to replace the present plant over the next five years.

The total workforce of the facility is 45 and there is little turnover reported. All of the alleged health problems were reported from among the 32 workers (and their families) of the sewage treatment division. The 13 "upstream" workers in the collection division were not affected. All of the 8 affected workers were among the 19 "operators" or "maintenance" personnel of the treatment division who are more or less continuously exposed to aerosolized sludge. The 13 unaffected treatment division workers' jobs involved only occasional or light exposures.

IV. LITERATURE REVIEW

A critical review of the literature has revealed little or no evidence of community (1)(2) or occupational (3)-(6) health problems associated with exposure to viable wastewater pathogens. However, occupational exposures to toxic chemicals (7)-(8) and to other non-viable agents (10) have resulted in serious health hazards for sewage treatment workers.

At a recent EPA-sponsored symposium on Wastewater Aerosols and Disease (9/19-21/79), Dr. C. S. Clark noted that the "few situations where viable sewage pathogens have caused adverse health effects were usually assocated with sewage farming with untreated wastes or with other contact with essentially raw sewage" (5)(8)(11)-(16). Although new employees in the wastewater industry sometimes experience gastrointestinal illness or dysentery during the first year of employment, they appear to have no unusual ill effects thereafter (11)(17).

Dr. Clark's group has analyzed about one half of the employment records and death certificates of a cohort of about 1,000 former Chicago sewage treatment employees for whom proportionate mortality rates (PMR) have not been significantly different from the expected death rates for several major disease groupings in a comparison with white males in Illinois stratified by age and year of death (12). These findings were true for the workers as a whole, for several employee subgroups by job classification, and for length of employment (i.e., "exposure" or "dose"). His findings did not support an earlier study by R. B. Dean at the University of Copenhagen who found the "Copenhagen sewer workers were dying earlier than controls of comparable age, with many workers expiring in the first year after retirement and with a highly significant difference in the observed number of cancer deaths caused by pancreatic cancer compared to that expected from the national experience in Denmark" (18). However, Dean's analysis was based on death certificates for 33 men among a cohort of 142 sewer workers employed for at least one year from 1957-1973 and these Copenhagen workers were exposed to the confined environments of sewers while Clark's study population was employed in the relatively more open environments of sewage treatment plants.

There have been no indications of an excess risk of chronic obstructive pulmonary disease (COPD) or coronary artery disease (CAD) associated with this occupation.

Basic science studies have documented the presence of mutagenic chemicals in wastewater treatment effluents (19)-(24). However, there have been no case reports or surveys of reproductive hazards associated with sewage treatment work despite the myriad of potentially harmful biological and chemical agents which these workers may inhale, swallow, and otherwise absorb. Recent review articles have emphasized the

potential risks to offspring from parental occupational exposures as well as the methodological problems inherent in the recognition and evaluation of these reproductive hazards (25)-(29). NIOSH has acknowledged the importance of the need for such studies by the establishment of a research initiative on occupationally related reproductive hazards (30).

The only environmental agent which has been demonstrated to cause CAD is carbon disulfide (31)(32). Withdrawl from exposure to nitroesters mimics the angina of CAD and may cause sudden death by coronary arterial spasm, but does not cause the atheromatous disease (33). The risk of onset of CAD attributable to cigarette smoking alone is 25% and life style or genetic/metabolic risk factors probably do not account for the balance of the multifactorial etiology of CAD (34). It is likely that other environmental/occupational agents will be identified as contributing to the risk of CAD.

In any case, a number of agents which act on the nervous system, cardiovascular system, or bronchopulmonary system may exacerbate pre-existing CAD or COPD in a variety of ways and some of these agents may well be present in aerosolized sludge or sewer gases (35)(36).

V. METHODS AND MATERIALS

A. Environmental

Sioux Falls treatment plant provides treatment for a population of approximately 83,000, plus additional treatment for numerous commercial and industrial users. Major contributions originate from "wet process" industrial wastes, the most significant of which are John Morrell and company (Meat Packing Firm), Meilman Foods, Sioux Falls Stockyards, Land-O-Lakes-Dairy, Terrace Parking Dairy, and Sioux Falls Rendering.

The industrial wastes are of such significance that pretreatment of the influents from the commercial operations is required prior to combining the flow with the domestic flow in the treatment plant.

Domestic waste influents undergo primary sedimentation, aeration, final clarification, and chlorination before discharging. Industrial influents undergo a primary flocculator, then clarification, filtration through a primary trickling filter, intermediate clarification, secondary trickling filtration, and secondary clarification. (37)

In addition to the above treatment processes both industrial and domestic influents flow through a bar screen, degritter, and anaerobic digesters. Each of these three areas were of concern in the evaluation of the plant. The bar screen, primarily because of materials that may have to be manually handled by plant personnel; the degritter, because of potential build-up of septic waste; and the digester, for the potential off-gases that may have an effect on the workers.

An INTERSCAN ^{R} hydrogen sulfide (H_2S) meter* was used throughout the plant to check the levels of H_2S.(38) Hydrocarbons were sampled in the digester area to ascertain whether toxic levels of contamination were present from the combustion of gases in this process. The sampling train for measuring hydrocarbons consisted of a charcoal tube and a sampling pump. Both long-term (8 hour) and short-term (1 hour) samples were taken.

B. Medical-Epidemiological

We conducted personal interviews with each of the 8 "sentinel" workers and their family or surviving spouse. With the informed consent and cooperation of these individuals and city authorities, we conducted a review of employment, medical, personnel, and other records.

Many of the other 24 treatment division workers were interviewed briefly during the course of our site visit.

VI. EVALUATION CRITERIA

A. Environmental

	NIOSH Evaluation Criteria	Reference
Hydrogen Sulfide	10 ppm/10 minutes (ceiling)	(39)

It is known that high concentration of H_2S, (in excess of 900 ppm) can cause immediate death. The H_2S is absorbed in the blood stream via inhalation and within a few seconds may cause unconsciousness and paralysis of the respiratory center with anoxia. Pulmonary edema and bronchial pneumonia may ensue if a worker were to survive a high exposure to H_2S. Chronic exposure to lower levels may cause headaches, irritation to mucous membranes, fatigue, irritability, insomnia, and eye irritation.

NIOSH recommends that exposure to hydrogen sulfide (H_2S) be controlled so that no employee is exposed to ceiling concentrations greater than 10 ppm as determined by a sampling period of 10 minutes during a work shift. During the work shifts, evacuation of the area should be required if the concentration exceeds 50 ppm. (Refer to Appendix A for more information on H_2S).

*Mention of Company names or products does not constitute Endorsement by the National Institute for Occupational Safety and Health.

Measurements with charcoal tubes indicated that toluene and mineral spirits were detectable but in very low concentrations in the rack room.

B. Medical-Epidemiological

Birth defects are personal tragedies for the families involved. The risks for these defects may be increased by a variety of factors--e.g., anatomic or genetic defects; environmental, occupational, or iatrogenic (medical treatment) exposures; and life-styles, habits, or behaviors. A consistent pattern of defect, especially when clustered in a personal or temporal fashion, prompts the need for identification of a common exposure as was demonstrated with phocomelia in the offspring of mothers treated with thalidomide during the organogenesis stage of their pregnancy. Therefore, affected families were interviewed and hospital records were reviewed to assess the alleged birth defects for such patterns.

Heart disease is the most common reason given for the cause of sudden unexpected death on death certificates. However, autopsy data provides the most reliable diagnostic criteria for cause of death. When death certificate diagnoses have been evaluated they have been found to be very unreliable (40). A review of city personnel records was conducted to evaluate the feasibility of a cohart analysis of vital status, should there be evidence of a confirmed cluster of a particular heart disease.

VII. RESULTS and DISCUSSIONS

A. Environmental

The levels of hydrocarbons were only trace amounts. There were three areas of primary concern as a result of this survey where workers may be exposed to concentrations of H_2S exceeding the recommended standard (See Table 1):

1. The area near a manhole between the degritter building and compressor building had a concentration of H_2S exceeding the TLV. This site was measured at various times over 2 days and each measurement exceeded the value of 20 ppm on the meter.

2. The heating building uses gases from the digester for fuel. The pumping system that was transmitting the gases had a leaking seal on a pump near the northwest corner of the building. This leak was pointed out to the night foreman during the survey.

3. Grit that comes into the plant is removed by a cyclone system. This material is not aerated and moves very slowly through the system, thus anaerobic conditions are created. Readings fluctuated from 8 ppm to 20 ppm during the survey in this area.

Other areas also may have potential for high H_2S concentrations depending on the operation and maintenance of the systems. Pump stations, the Rack Room, and underground areas where piping supplies gases from the digester may at sometimes have high concentrations of H_2S, although they did not during this survey.

It should be noted that no one spent much time in any of the above-mentioned areas while we were surveying the operations.

The rack is designed to remove rags, paper, and other materials from the influent to the plant's domestic system. Plant personnel went into the building where this was located and removed materials from the rack with a rake. They were placed in a wheel barrow and hauled a short distance to an incinerator just west of the pack building. No worker was observed wearing respirators, aprons, or protective clothing such as gloves when this operation was performed.

There are many areas underground at this facility. The potential for oxygen deficient atmospheres exists in these areas. (41)

B. Medical-Epidemiological

Table 2 depicts the distribution of the sex, age, and work experience of the treatment and collection division employees. Although not specifically indicated, all personnel are Caucasians. Almost all of the operators and maintenance personnel are cigarette smokers and only a few of the lab and office personnel smoke. The 8 sentinel cases described below occurred among workers (or their spouses) who were operators or maintenance employees of the treatment division.

Re: "Heart Diseases": Of 4 reported "recent heart diseases", police, hospital, and autospy reports confirm that there was:

(1) A massive anterior wall myocardial infarct on 11/5/79 complicated by congestive heart failure secondary to aneurysmal dilatation of the infarcted ventricle in a 36-year-old white male with no known risk factors except a greater-than-80-pack-year smoking history in a 4-pack/day smoker;

(2) A poorly-documented, "mild, inferior wall myocardial infarct or possibly myositis" 12 years ago at age 53 in a presently 64-year-old white male with chronic obstructive pulmonary disease (COPD), dysrhythmias, angina, carotid bruit, ulcerative colitis, status-post gall bladder surgery, and a greater-than-80-pack-year smoking history with no evidence of EKG changes since 1968;

(3) The recent demise on 10/13/79 of a 58-year-old white male with a 30-pack-year smoking history who was killed by traumatic rupture of his aorta and right ventricle in a single-car accident in which witnesses observed that he was "asleep or unconscious" prior to hitting a tree on his way home from his second 8-hour shift in 24 hours. At autopsy he had coronary artery disease (CAD) but no fresh coronary occlusion or evidence of toxic overdose;

(4) On 10/15/78, a 45-year-old white male, with a 40-pack-year smoking history, COPD, and 12 years status-post thyroidectomy for cancer, died as a result of the complications of severe acute pericarditis and myocarditis with no evidence of CAD at autopsy where the incidental finding of bilaterial pheochromoblastomas was noted.

Personnel records are maintained by the city for the previous 10 years, and for all deceased employees whose beneficiaries are still living. A review of these records provided the names of 109 present or former employees: 45 currently employed (32 in the treatment division and 13 in the collection division); 36 former employees who had been dismissed, discharged, terminated, or had resigned for unspecified reasons; 13 former employees who had retired on pension; and 15 former employees who were known to be deceased. Of the 15 known deaths, 2 were autopsy-confirmed (#3 and #4 discussed above) and death certificates were available for 5 of the remaining 13 former employees. All 5 death certificates attributed the sudden unexpected deaths to coronary occlusion; all deaths occurred at home; and the ages at death were: 49, 62, 65, 67, and 73. The deceased (two operators, two maintenance men, and a superintendant) had all been employed in their positions for 10 to 30 years. Records were incomplete concerning the occupational history, present location, and health status of most of the 49 living former employees as well as the 8 deceased employees for whom death certificates were not available.

Re: Birth Defects: Of four alleged "abnormal pregnancies in the past 2 years," the data indicated:

(5) Birth of a non-viable post-mature female with "trisomy 18" syndrome on 1/20/74 to a 27-year-old gravida 2, para 1 mother with no known personal or family risk factors except a greater-than-20-pack-year smoking history;

(6) Birth of an apparently normal full-term female on 5/6/76 who failed to thrive, was diagnosed as having congenital ventro-septal defect (VSD) with anomalous aortic arch and vascular ring as well as an acquired atro-septal defect (ASD), and who died during surgical repair of the defects because of inadvertant brain perfusion via the aortic anomaly. The 28-year-old mother had a normal pregnancy, and no known risk factors;

(7) Recognition of a left lower extremity monoparesis as cerebral palsy in a 20-month-old female who had been delivered on 6/7/76 by pitocin induction 72 hours following amnionitis and premature rupture of membranes at 30 weeks of gestation. The 26-year-old mother had no known risk factors apart from the perinatal infection and prematurity;

(8) An incomplete spontaneous abortion on 10/27/76 at 6-7 weeks of gestation in a 26-year-old non-smoking epileptic mother who has been on 40 mg of Dilantin daily for 12 years. The autopsy reported benign necrotic products of conception.

All of these mothers have had prior and subsequent successful pregnancies. Only one of them is still considering additional children.

Re: "Respiratory Weakness"; None of the workers related complaints of dyspnea, chest tightness, wheezing, or chest pain in association with their work. About 80% of the workers at the sewage treatment plant are smokers. It is not our intent to "blame" smokers for their increased susceptibility to respiratory problems which occur more frequently, more severely, and in a more prolonged fashion in such individuals. However, in our interviews we were not convinced that there was a significant respiratory problem present which could be distinguished from the effects of smoking.

Respiratory complaints did not seem to be as important to the workers as the other problems except that they were concerned that they were being intoxicated by inhalation and swallowing of aerosols and sewer gas with sulfide odors.

VIII. DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS.

A. MEDICAL

There was no pathophysiological nor temporal consistency nor clustering of either birth defects or heart disease among the sentinel cases.

The basis for the unconsciousness of the 58-year-old accident victim with autopsy-diagnosed CAD is not possible to resolve, although the forensic pathologist stated that he doubted there had been a coronary occlusion or myocardial infarct ante-mortem. A review of available death certificates for five former employees revealed the assigned cause of death in all 5 cases to be "coronary occlusion" which is a notoriously unreliable presumption in the absence of autopsy data (40).

National incidence rates of reported spontaneous abortion in the first trimester range from 15-25% of all pregnancies even in the absence of risk factors as well known as Dilantin's anti-folic acid effects according to the Birth Defects Branch of CDC. National incidence rates for congenital cerebral palsy, where there is reason to suspect a

perinatal or prenatal etiology, range from 1 to 3 cases per 100 live births according to the United Cerebral Palsy Association. Approximately 9 births per 1000 are complicated by a cardiovascular malformation. In a series of 2310 cases of cardiac malformations diagnosed at birth, ventricular septal defect (VSD) occurred in 30.5% which gives an approximate incidence of 3/1000 in this series, recognizable at birth (recall that the VSD in the Sioux Falls infant was not diagnosed until 8 weeks of age) (42). The frequency of autosomal trisomies 13, 18, and 21 among live-born infants is about 1 per 500 live-born infants; for trisomy 18 alone the incidence is 1 per 5000 (43). The CDC's Birth Defects Monitoring Program has reported a nationwide doubling of the incidence of VSD over the past ten years which could not be attributed to increased recognition and reporting (44).

Because of the small size of the workforce, the difficulty in establishing a complete cohort for epidemiological study, and the lack of pathophysiological or temporal consistency among the sentinel cases, NIOSH investigators decided not to pursue this problem in any greater detail. This decision was supported by consultation with the Industry-wide Studies Branch of DSHEFS, NIOSH and the Birth Defects Studies Branch of CDC.

The study of reproductive and cardiovascular risks among sewage treatment workers could be approached with greater power by case-control methods among larger populations such as those being evaluated by Dr. C. S. Clark's group at the University of Cincinnati.

A. ENVIRONMENTAL

Results of the environmental survey showed that a potential exists for worker exposure to concentrations of H_2S which are considered toxic. The survey in July was made at a time when all windows were open and a 25 mph wind was blowing throughout the area. Therefore, little chance existed to find conditions where H_2S in buildings might exceed the NIOSH recommended standard.

The following recommendations were made:

1. Replace leaking valves and equipment where workers could receive an exposure to H_2S.

2. Consider purchasing a monitoring device and train workers to use the device especially when working on systems where H_2S may be present.

3. Institute a training and educational program for workers and plant personnel in the areas of entry into confined spaces.

4. Require workers to wear protective clothing when handling materials from the trash rack.

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TABLE 1

RESULTS OF INTERSCAN ^{R} H_2S METER MEASUREMENTS AT SIOUX FALLS' SEWAGE TREATMENT PLANT (7/25-26/81)

TYPE OF SAMPLE	OPERATIONS	TIME OF MEASUREMENT (Military Time)	PPM/ 10 Min. Sample
Area	Compressor Room	0001	.5
		0200	.3
		0400	.4
		0600	.4
		0800	.4
Area	Rack Room	0010	.5
		0210	.4
		0410	.5
		0610	.5
		0810	.5
Area	Influent	0012	.4
		0212	.4
		0412	.3
		0612	.3
		0812	.3
Area	Degritter	0015	.7
		0215	.6
		0415	.5
		0615	.5
		0815	20
Area	Air Compressor Boiler Room	0020	.9
		0220	.8
		0420	.8
		0620	.6
		0820	.5
Area	Boiler Room Pump	0024	20.0
		0224	20.0
		0424	20.0
		0624	20.0
		0824	20.0
Area	Sewer Manhole	Various Times	20.0

APPENDIX A

EFFECTS OF HYDROGEN SULFIDE INHALATION ON HUMANS*

(NOTE: 1.5 mg/m^3 of hydrogen sulfide is approximately 1.0 ppm of hydrogen sulfide)

No. of Subjects	Concentration (mg/m^3)	Duration of Exposure	Reported Effects
1	17,000	-	Death
1	2,800-5,600	20 min	Death
10	1,400	1 min	Death (1/10), unconsciousness, abnormal ECG
342	1,400-2,800	20 min	Hospitalization of 320, death of 22 including 13 in hospital, residual nervous system damage in 4
5	1,400	Instant	Unconsciousness, death
1	1,400	25 min	Unconsciousness, low blood pressure, pulmonary edema, convulsions, hematuria
4	400-760	-	Unconsciousness
1	320	20 min	Unconsciousness, arm cramps, low blood pressure
78	20-35	-	Burning eyes in 25, headache in 32, loss of appetite in 31, weight loss in 20, dizziness in more than 19
6,500	15-20	4-7 hr	Conjunctivitis
City of Terre-Haute	0.003-11	Intermittent air pollution episodes over a 2-month period	Complaints of nausea (13), headache, shortness of breath (4), sleep disturbance (5), throat and eye irritation (5)

*Obtained from Reference 39 of this report; Table III-1, page 61.