American Journal of Industrial Medicine 23:751–761 (1993)

Respiratory Function in Sewage Workers

Eugenija Zuskin, MD, DSci, Jadranka Mustajbegovic, MD, MrSci, and E. Neil Schachter, MD

Respiratory symptoms and ventilatory capacity were studied in a group of 74 sewage workers employed in cleaning the city sewage system of Zagreb, Croatia. Workers were studied by their work stations: closed channels (N = 26), drainage (N = 31), and other sewage workers (N = 17). The prevalence of chronic respiratory symptoms was higher in closed channel and drainage workers than in controls, particularly for chronic cough (range: 41.9–46.2% vs. 14.3%), chronic phlegm (range: 38.7–46.2% vs. 14.3%), chronic bronchitis (range: 32.3–42.3% vs. 8.6%), and chest tightness (range: 29.0–53.8% vs. 0%). In the first two groups of sewage workers there was a high prevalence of acute symptoms which developed during the work shift, being particularly pronounced for eye irritation (range: 16.1–26.9%), dyspnea (16.1–23.1%), dizziness (range: 6.5–23.1%), throat burning (9.7–19.2%), and skin irritation (range: 22.6–26.9%). Baseline ventilatory capacity was significantly decreased compared to predicted values in sewage workers; in particular, values for FEF50 and FEF25 were reduced, suggesting obstructive changes in smaller airways. Our data indicate that sewage workers experience frequent acute and chronic respiratory symptoms and exhibit objective evidence of respiratory dysfunction.

Key words: sewage, respiratory symptoms, lung function, occupational hazards

INTRODUCTION

Work in the sewage system presents constant exposure to noxious gases, vapors, and fumes, as well as explosive substances (such as methane) and infectious agents. In addition, this work is carried out in confined spaces with a lack of adequate ventilation. Sewage workers perform numerous specific tasks, each with its own special hazardous exposures. These include dewatering plant workers, incinerator workers, aeration plant workers, etc. A number of studies have investigated the health of sewage treatment workers and have related these findings to workplace exposures.

McCunney [1986] described the potential health hazards associated with work at wastewater treatment plants; these hazards included infectious agents (bacteria, viruses, and protozoa) from domestic waste, as well as toxins, heavy metals, and other inorganic hazardous substances in industrial wastes. Most occupational studies

Andrija Stampar School of Public Health, Zagreb, Croatia (E.Z., J.M.).
Mount Sinai School of Medicine, New York, NY (E.N.S.).
Address reprint requests to Dr. E. Neil Schachter, Mount Sinai School of Medicine, One Gustave L. Levy Place, New York, NY 10029-6574.
Accepted for publication July 30, 1992.

of this industry have focused on looking for evidence of previous or concurrent infections with specific disease pathogens or parasites in wastewater treatment plants [Clark et al., 1976, 1979]. Sewage and wastewater treatment workers experience an increased frequency of diarrhea, headache, eye irritation, dizziness, sore throat, skin disorders, and gastrointestinal symptoms when compared to controls [Morse et al., 1979; Sekla et al., 1979; Lundholm and Rylander, 1983; Elia et al., 1983; Scarlett-Kranz et al., 1987]. Similar symptoms have been found in a facility composting household garbage where no industrial chemicals were present. Clark et al. [1979] found that newly employed sewage workers were more likely to report gastrointestinal signs than experienced workers, suggesting that immunity or tolerance may develop to some of the toxins or infectious agents present. The investigation of Nethercott and Holness [1988] described an "influenza-like" syndrome, with cough, sputum production, wheezing, sore throat, fever, and skin complaints in sewage plant treatment workers who also had reduced lung function.

Ozonoff et al. [1987] reported that among community residents exposed to airborne hazardous wastes there was an increased prevalence of complaints referable to the respiratory system (wheezing, shortness of breath, chest discomfort, persistent colds, cough), constitutional complaints (fatigue, bowel dysfunction), as well as irregular heart rhythms and irritation of the eyes and nose. In sewage treatment workers, serum immunoglobulins, white blood cell counts, and platelet counts were elevated. These workers showed increased levels of C-reactive protein and fibrinogen degradation products [Rylander et al., 1977; Mattsby and Rylander, 1978]. A "sewage worker's syndrome" was described by Clark et al. [1977], who found a high level of IgA and abnormal liver function studies (SGOT). Lundholm and Rylander [1983] suggested that many symptoms among sewage workers were caused by toxins from Gram-negative bacteria.

There are currently no available data on the respiratory function of sewage workers employed in cleaning and maintaining an underground sewage system. In our study, we investigated the prevalence of respiratory symptoms and the ventilatory capacity in a group of sewage workers performing these tasks in the city of Zagreb, Croatia.

SUBJECTS AND METHODS

Working Environment

A number of chemicals enter the Zagreb sewage system as industrial or household effluent. Pathogenic bacteria, viruses, the cysts of protozoa, the ova of helminths, and fungal spores have been found in sewage sludge [Babish et al., 1984; Majeti and Clark, 1981]. Domestic waste contains human feces which is the major component implicated in the spread of bacterial, viral, protozoan, fungal, and helminth disease. Classic water-borne bacterial infections include cholera, salmonella, typhoid fever, shigella, hepatitis, and amebic dysentery.

Only a small number of the toxins in sewer sludges have been identified. The main toxic substances associated with industrial waste include: a) organic compounds (gasoline, pesticides, cancer causing agents); b) acids and alkali; and c) radioactive material. Mumma et al. [1984] and Babish et al. [1984] reported high concentrations of toxic metals in sludges from specific municipal plants. Many noninfectious toxins, such as mercury, zinc, silver, copper, lead, cadmium and other heavy metals, anti-

mony, arsenic, solvents including benzene, and complex hydrocarbons have been identified in wastes [Landrigan, 1989]. However, even sludge derived from relatively small communities, representing largely domestic users, contains many toxic elements resulting from nonindustrial activities.

Among our studied workers, the most potentially hazardous job was that performed in confined and unventilated areas (e.g., sewers, tunnels, pipes, wet wells, manholes, pits, pumping stations, and sludge digestors). In these confined spaces, there is usually little or no ventilation, little room for movement, and few exits or entrances. Confined spaces can be especially dangerous because gases can rapidly accumulate at the bottom of these areas or in isolated pockets. Our studied population was divided into three groups: 1) those working in closed channels; 2) those cleaning an open drainage system; and 3) others (mechanics and vehicle drivers). The work in the closed channels was performed manually, while cleaning of the drainage system was done by machines. Results of the environmental studies where our workers were employed documented the presence of carbon monoxide (CO), carbon dioxide (CO_2), ammonia (NH_3), hydrogen sulfide (H_2S), cyanide (HCN), trichlorethylene (C_2HCL_3), methane (CH_4), ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), ethylene (C_2H_4), and propylene (C_3H_6). These pollutants were measured with Drager tubes. In addition, we measured the varying concentrations of phenol (0.18–3.01 mg/L), chloride (61–157 mg/L), ammonia (15.4–31.3 mg/L), sulphate (69–147 mg/L), nitrites (0.02–0.20 mg/L), cyanide (0.02–0.04 mg/L), chromium (0.13–4.45 mg/L), copper (0.01–0.07 mg/L), nickel (0.03–0.07 mg/L), lead (0.06–1.16 mg/L), and cadmium (0.002–0.006 mg/L). These latter pollutants were measured by spectrophotometry and gas chromatography and expressed as mg/L of wastewater.

Subjects

We investigated a group of 74 sewage workers, representing 95% of all workers employed in the municipal system of Zagreb. The mean ages of the 26 closed channel and 31 drainage workers were similar: 33 and 36 years, respectively, with a mean duration of exposure of 11 and 12 years. The third group of 17 "other" workers was older (mean age 46 years) with a longer duration of employment (mean exposure 24 years). There were 40 (54%) sewage system workers who were regular smokers, smoking on the average 20 cigarettes daily. To accommodate the difference in ages and work exposures of the worker population, separate control groups were used: 35 bottling plant nonexposed workers for closed channel and drainage workers on the one hand, and 15 fruit juice workers for "other" sewage workers on the other hand. These controls were of similar age and smoking habits, classified as nonsmokers and smokers (current and former). The prevalences of respiratory symptoms were evaluated in these control groups. The demographic data of the workers and control groups are shown in Table I.

Respiratory Symptoms

Chronic respiratory symptoms were recorded in the 74 sewage workers and in the 50 control workers using the British Medical Research Council questionnaire on respiratory symptoms [1960] with additional questions on occupational asthma [WHO, 1986]. For all workers, a detailed occupational history as well as information about their smoking history was recorded. The following definitions were used:

TABLE I. Demographic Characteristics of Sewage Workers and Control Groups Studied—Zagreb, 1990

Group		N	Mean age (yrs)	Mean exposure (yrs)	Smoking habit (pack/year)
Closed channels	Smokers	13	32 ± 9[a]	12 ± 8	13 ± 8
	Nonsmokers	13	33 ± 13	10 ± 11	
Drainage	Smokers	18	35 ± 12	14 ± 10	17 ± 12
	Nonsmokers	13	37 ± 10	10 ± 8	
Control	Smokers	18	34 ± 11	11 ± 9	14 ± 9
	Nonsmokers	17	38 ± 10	15 ± 11	
Other sewage workers	Smokers	9	43 ± 11	20 ± 11	24 ± 16
	Nonsmokers	8	49 ± 5		27 ± 5
Control[b]	Smokers	9	43 ± 10	21 ± 9	25 ± 12
	Nonsmokers	6	46 ±11	24 ± 10	

[a]The data are presented as mean ± SD.
[b]No difference was found between exposed and control workers.

chronic cough or phlegm: cough and/or phlegm production for at least 3 months per year;
chronic bronchitis: cough and phlegm for a minimum of 3 months a year and for not less than 2 successive years;
dyspnea grades: grade 3—shortness of breath when walking with other people at an ordinary pace on level ground; grade 4—shortness of breath when walking at their own pace on level ground;
occupational asthma: recurring attacks of dyspnea, chest tightness, and pulmonary function impairment of the obstructive type diagnosed by physical examination and spirometric measurements during exposure to dust at or following work.

In sewage workers, acute symptoms during the work shift such as cough, dyspnea, chest tightness, irritation or dryness of the throat, secretions, dryness or bleeding of the nose, dizziness, headache, and skin irritation were specifically recorded. Acute symptoms were not ascertained among controls.

Ventilatory Capacity

Ventilatory capacity was measured in 74 sewage workers by recording maximum expiratory flow-volume (MEFV) curves using a portable flow-volume spirometer (Autospiror Hi-498, Chest Co., Tokyo, Japan). The spirometer was calibrated daily. Measurements were corrected to BTPS. Measurements were performed on the first working day of the week (Monday) at the beginning of the morning work shift. The forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), and maximum flow rates at 50% and the last 25% of the control vital capacity were measured on these curves. At least three MEFV curves were recorded and the best value was used in the analysis. The measured Monday preshift value of ventilatory capacity was compared with the expected normal values of Quanjer [1983].

RESULTS

Respiratory Symptoms

Data on the prevalence of chronic respiratory symptoms are presented in Table II. Symptoms in general were more prevalent among sewage workers. In particular, a high prevalence of chronic cough, chronic phlegm, chronic bronchitis, and chest tightness was found among the workers employed in the closed channel and drainage groups. The prevalence of symptoms in these two groups was significantly higher than those of controls ($p < 0.01$ or $p < 0.05$). The third group of "other" sewage workers had considerably lower prevalence of all symptoms than the previous two groups. The difference in symptom prevalences between "other" sewage workers and their respective controls was significant only for chest tightness ($p < 0.05$). Smoking and nonsmoking sewage workers had similar prevalences for all chronic respiratory symptoms; however, the cell sizes were small.

Prevalences of acute symptoms during the work shift are presented in Table III. Among closed channel sewage workers, the highest prevalences were recorded for eye irritation, headache, dizziness, dyspnea, and burning or dryness of the throat. Considerably fewer workers employed in drainage and "other" sewage workers complained of these acute symptoms compared to those in closed channels. There was a statistically significant difference between closed channel workers and the group of "other" sewage workers for dizziness and headache ($p < 0.01$).

Ventilatory Capacity

The data for ventilatory capacity in sewage workers analyzed by smoking status are presented in Table IV for FVC and FEV_1, and in Table V for FEF50 and FEF25. FVC in all workers was >80% of predicted and the mean values were not significantly different from predicted. Some study subjects demonstrated an FEV_1 less than 80%, although the mean data were >80%. Significant differences from normal values were seen for smokers (but not for nonsmokers). Most of the values of FEF50 and FEF25 were significantly lower than predicted (Table V). This was particularly pronounced in closed channel workers whose values were regularly below 80% of predicted. Smokers had, in general, lower values than nonsmokers. However, for closed channel workers, values were also abnormal in nonsmokers.

Comparison of the lung function of controls to that of workers is presented in Table VI. This table describes the proportion of workers with lung function less than 80% of predicted. Significant differences were calculated by χ^2 or Fisher's exact test.

DISCUSSION

This study is the first to concentrate on the noninfectious respiratory health hazards of sewage workers. Our data indicate that cleaning and maintenance work in sewage systems presents a risk for the development of acute and/or chronic respiratory symptoms, as well as potentially serious effects on ventilatory capacity. This was particularly pronounced in workers employed in closed channels, whose jobs are very hazardous. Because of the small and limited spaces in the channels, these workers work in a confined position in very polluted areas. Although the job description of these sewage workers differed from those of sewage workers employed in sewage

TABLE II. Prevalence of Chronic Respiratory Symptoms in Sewage Workers and in Two Control Groups

Group	Mean age (yrs)	Mean exposure (yrs)	Chronic cough	Chronic phlegm	Chronic bronchitis	Dyspnea	Asthma	Chest tightness	Nasal catarrh	Sinusitis	Hoarseness
Closed channels	33	11	12[b]	12[b]	11[b]	4	0	14[b]	7	3	5
N = 26			46.2%	46.2%	42.3%	15.4%	0%	53.8%	26.5%	11.5%	19.2%
Drainage	36	12	13[b]	12[a]	10[a]	4	1	9[a]	7	2	3
N = 31			41.9%	38.7%	32.3%	12.9%	3.2%	29.0%	22.6%	6.5%	9.7%
Control	36	13	5	5	3	2	0	0	3	3	0
N = 35			14.3%	14.3%	8.6%	5.7%	0%	0%	8.6%	8.6%	0%
Other sewage workers	46	24	4	5	3	4	0	5[a]	6	1	3
N = 17			23.5%	29.4%	17.6%	23.5%	0%	29.4%	35.3%	5.9%	17.6%
Control	45	23	3	2	2	2	0	0	1	0	0
N = 15			20.0%	13.3%	13.3%	13.3%	0%	0%	6.7%	0%	0%

[a],[b]Difference between sewage workers and controls statistically significant: [a]$p < 0.05$; [b]$p < 0.01$.

TABLE III. Prevalence of Acute Symptoms During Work Shift in Sewage Workers

Group	Cough	Dyspnea	Throat		Eye	Nose			Dizziness	Headache	Skin
			burning	dryness	irritation	secretion	dryness	bleeding			irritation
Closed channels N = 26	4 15.4%	6 23.1%	5 19.2%	4 15.4%	7 26.9%	0 0%	3 11.5%	2 7.6%	6* 23.1%	7* 26.9%	7 26.9%
Drainage N = 31	3 9.7%	5 16.1%	3 9.7%	3 9.7%	5 16.1%	1 3.2%	2 6.5%	2 6.5%	2 6.5%	0 0%	7 22.6%
Other sewage workers N = 17	3 17.6%	3 17.6%	1 5.9%	1 5.9%	1 5.9%	0 0%	2 10.8%	0 0%	0* 0%	0* 0%	1 5.9%

*Difference in the prevalence of dizziness and headache statistically significant between the first and the third group ($p < 0.01$).

TABLE IV. Ventilatory Capacity in Sewage Workers

		FVC			FEV_1		
	Group	Measured L[a]	% predicted	Difference measured-predicted p	Measured L	% predicted	Difference measured-predicted p
	N = 26	4.89 ± 0.65[b]	102.7	NS[c]	3.86 ± 0.63	96.7	NS
Closed channels	Smokers						
	N = 13	4.87 ± 0.57	102.1	NS	3.84 ± 0.49	95.8	<0.04
	Nonsmokers						
	N = 13	4.92 ± 0.75	103.6	NS	3.88 ± 0.77	97.7	NS
	N = 31	5.19 ± 0.69	105.1	NS	3.88 ± 0.71	93.7	<0.01
Drainage							
	Smokers						
	N = 18	5.14 ± 0.80	105.1	NS	3.67 ± 0.78	89.1	<0.01
	Nonsmokers						
	N = 13	5.25 ± 0.53	105.0	NS	4.16 ± 0.48	100.0	NS
	N = 17	4.53 ± 0.82	97.8	NS	3.28 ± 0.68	87.0	<0.001
Others	Smokers						
	N = 9	4.77 ± 0.81	102.7	NS	3.47 ± 0.77	90.6	<0.05
	Nonsmokers						
	N = 8	4.25 ± 0.79	92.6	NS	3.06 ± 0.53	82.7	<0.01

[a]L, liters.
[b]Data are presented as mean ± SD.
[c]NS, difference statistically not significant ($p > 0.05$).

treatment plants, data from treatment plants suggest that both groups of workers are, to some extent, exposed to similar noxious agents and develop similar symptoms.

Sewage systems receive varying degrees of domestic and industrial waste, thus, health concerns may depend on the respective types and concentrations of materials handled. The most likely route of exposure to noxious agents among sewage workers is by inhalation of aerosols or by hand-to-mouth transmission. Concern for the health and safety of these workers has focused on infectious diseases and metabolic intoxications, but, clearly, respiratory hazards must also be considered.

Lundholm and Rylander [1980] described occupational symptoms such as nausea, headache, and diarrhea among compost workers. In their study, the number of airborne Gram-negative bacteria was high where household garbage was agitated. Similarly, respiratory impairment among workers in a garbage-handling plant was described by Sigsgaard et al. [1990]. A study of a sewage plant in Memphis, Tennessee suggests that workers experience acute health effects such as eye irritation, dizziness, skin irritation, and other symptoms following exposure to pesticides [Elia et al., 1983]. Similarly, Clark et al. [1979] observed an increased level of gastrointestinal illness in newly hired sewage-exposed workers compared to experienced employees and controls. Despite monitoring of stool and serum samples, these investigators failed to find consistent evidence for bacterial, viral, or parasitic infections among sewage treatment workers. Nevertheless, Clark et al. [1977] demonstrated significantly elevated levels of Coxsackie B3 and B5 viral antibody levels in sewage treatment workers as compared to controls. Higher incidences of colds and flu have

TABLE V. Ventilatory Capacity in Sewage Workers

		FEF50			FEF25		
	Group	Measured L/s[a]	% predicted	Difference measured-predicted p	Measured L/s	% predicted	Difference measured-predicted p
	N = 26	4.14 ± 1.42[b]	79.8	<0.01	1.65 ± 0.82	71.4	<0.01
Closed channels	Smokers						
	N = 13	4.13 ± 0.97	79.6	<0.01	1.60 ± 0.75	69.2	<0.01
	Nonsmokers						
	N = 13	4.40 ± 1.81	80.0	<0.01	1.69 ± 0.93	73.5	<0.01
	N = 31	4.60 ± 1.60	86.6	<0.01	1.81 ± 0.83	75.4	<0.01
Drainage	Smokers						
	N = 18	4.17 ± 1.69	79.1	<0.01	1.50 ± 0.70	63.3	<0.001
	Nonsmokers						
	N = 13	5.21 ± 1.30	87.0	NS[c]	2.25 ± 0.83	91.5	NS
	N = 17	4.09 ± 1.67	83.1	<0.04	1.48 ± 0.65	71.5	<0.001
Others	Smokers						
	N = 9	3.93 ± 1.28	78.8	<0.05	1.46 ± 0.65	68.2	<0.001
	Nonsmokers						
	N = 8	4.36 ± 1.11	87.9	NS	1.50 ± 0.70	75.0	NS

[a]L/s, liters per second.
[b]Data are presented as mean ± SD.
[c]NS, difference statistically not significant ($p > 0.05$).

TABLE VI. The Distribution of Workers With Ventilatory Capacity Tests Less Than 80% of Predicted

	Group	N	FEV_1 # (%)	FEF50 # (%)	FEF25 # (%)
	Smokers	13	0	15.4	53.8
Closed channels	Nonsmokers	13	0	46.2[a]	53.8[b]
	Smokers	18	22.4	55.6[a]	66.7[a]
Drainage	Nonsmokers	13	38.5[b]	23.1	30.8
Other sewage workers	Smokers	9	22.2	33.3	77.8
	Nonsmokers	8	50.0[b]	37.5	50.0[a]
	Smokers	27	7.4	11.1	22.2
Controls	Nonsmokers	23	0	4.3	4.3

[a],[b]Difference between sewage and control workers statistically significant: [a]$p < 0.05$; [b]$p < 0.01$.

been reported by Ledbetter et al. [1973]. However, the authors considered that the hazards of respiratory disease from working at a wastewater treatment center were quite small.

Most sewage-related disease outbreaks have been attributed to contact with raw sewage wastewater and raw sludges. The use of wastewater systems for the disposal of industrial wastes creates the potential for the exposure of sewage workers to

hazardous chemicals that may be present in these wastes [Elia et al., 1983]. Recently, Chase and Shields [1990] described health hazards in waste site workers from exposure to polychlorinated biphenyls (PCBs).

Airborne toxins from wastewater may also represent a health hazard to nearby community residents. Household wastes (including automotive oil, paint, solvents, and pesticides) are hazardous to health. The results of other investigators suggest that a major contributor to environmental contamination is household waste [Stanek et al., 1987].

The respiratory system is not the only organ at risk from sewage waste exposure. The occupational exposure of sewage workers to hexachlorocyclopentadiene resulted in proteinuria and elevation of serum lactic dehydrogenase in addition to symptoms such as eye irritation, headache, and throat irritation [Morse et al., 1979].

Airborne irritant contact dermatitis among workers employed in a sewage treatment facility has been described by Nethercott [1981]. Contamination of the workplace and worker's clothing by sludge proved to be the cause of the problem. Health hazards of workers at waste incineration plants have recently been described by Gustavsson [1989] and Landrigan [1989], who noted an increased prevalence of ischemic heart disease and lung cancer among these workers. Lafleur and Vena [1991] described significantly higher mortality for cancer of the larynx among sewage plant workers than in the general population.

This current study demonstrates for the first time in a systematic way the airway hazards of working with sewage. While the agent or agents responsible for the symptoms and physiologic changes have not been defined, these findings do warrant further studies and preventive measures. In order to prevent the development of acute and/or chronic respiratory and other symptoms, it is important for sewage workers to have suitable protective clothing, shoes, gloves, and masks; and in particular, the treatment process should be automated to the fullest extent possible. Sewage workers need to be educated on how to avoid infection and how to use protective measures in their daily work. In addition, a medical surveillance program should be carried out, including preemployment and periodic medical examinations in order to protect those workers with preexisting respiratory changes and/or sensitivity to noxious agents.

ACKNOWLEDGMENTS

Supported in part by grant JBP 733 from the National Institutes of Health, Bethesda, MD, grant no. R01-0H0 2593-02 from the National Institute for Occupational Safety and Health, Centers for Disease Control, Atlanta, GA, and by the Henry and Catherine Gaissman and the Miller Foundation, New York, NY.

REFERENCES

Babish JG, Stoewsand GS, Scarlett Kranz MS, Boyd JN, Ahrens VD, Lisk DJ (1984): Toxicologic studies associated with the agricultural use of municipal sewage sludge and health effects among sewage treatment plant workers. Regul Toxicol Pharmacol 4:305–321.

Bishop K, Ring SJ, Zoltai T, Manos CG, Ahrens VD, Lisk DJ (1985): Identification of asbestos and glass fibers in municipal sewage sludges. Bull Environ Contam Toxicol 34:301–308.

Chase KH, Shields PG (1990): Medical surveillance of hazardous waste site workers exposed to polychlorinated biphenyls (PCBs). Occup Med 5:33–37.

Clark CS, Bjornson AB, Schiff GM, Phair JP, Van Meer GL, Gartside P (1977): Sewage worker's syndrome. Lancet 1:1009.

Clark CS, Cleary EJ, Schiff GM, Linnemann CC, Phair JP, Briggs TM (1976): Disease risks of occupational exposure to sewage. J Environ Eng Div (Am Soc Civ Eng) 102:375–388.

Clark CS, Vanmeer GL, Linnemann CC, Bjornson AB, Gartside PS, Schiff GM, Trimble SE, Alexander D, Cleary EJ (1979): Health effects of occupational exposure to wastewater. In Pahren H, Jakubowski W (eds): "Wastewater, Aerosols and Disease." Springfield, VA: Nat Techn Inf Serv, pp 239–264.

Elia VJ, Clark CS, Majeti VA, Gartside PS, MacDonald T, Richdale N, Meyer CR, VanMeer GL, Hunninen K (1983): Hazardous chemical exposure at a municipal wastewater treatment plant. Environ Res 32:360–371.

Gustavsson P (1989): Mortality among workers at a municipal waste incinerator. Am J Ind Med 15:245–253.

Lafleur J, Vena JE (1991): Retrospective cohort mortality study of cancer among sewage plant workers. Am J Ind Med 19:75–86.

Landrigan PJ (1989): Incompletely studied hazards of waste incineration. Am J Ind Med 15:243–244.

Ledbetter JO, Hauck LM, Reynolds R (1973): Health hazards from wastewater treatment practices. Environ Letters 4:225–232.

Lundholm M, Rylander R (1980): Occupational symptoms among compost workers. J Occup Med 22:256–257.

Lundholm M, Rylander R (1983): Work related symptoms among sewage workers. Br J Ind Med 40:325–329.

Majeti VA, Clark CS (1981): Health risks of organics in land application. J Environ Eng Div (Am Soc Civ Eng) 107:339–357.

Mattsby I, Rylander R (1978): Clinical and immunological findings in workers exposed to sewage dust. J Occup Med 20:690–692.

McCunney RJ (1986): Health effects of work at wastewater treatment plants: A review of the literature with guidelines for medical surveillance. Am J Ind Med 9:271–279.

Medical Research Council Committee on the Etiology of Chronic Bronchitis (1960): Standardized questionnaire on respiratory symptoms. Br Med J 2:1665.

Morse DL, Kominsky JR, Wisseman CL, Landrigan PJ (1979): Occupational exposure to hexachlorocyclopentadiene. JAMA 241:2177–2179.

Mumma RO, Raupach DC, Waldman JP, Tong SSC, Jacobs ML, Babish JG, Hotchkiss JH, Wszolek PC, Gutenman WH, Bache CA, Lisk DJ (1984): National survey of elements and other constituents in municipal sewage sludges. Arch Environ Contam Toxicol 13:75–83.

Nethercott JR (1981): Airborne irritant contact dermatitis due to sewage sludge. J Occup Med 23:771–774.

Nethercott JR, Holness DL (1988): Health status of a group of sewage treatment workers in Toronto, Canada. Am Ind Hyg Ass J 49:346–350.

Ozonoff D, Colten ME, Cupples A, Heeren T, Schatzkin A, Mangione T, Dresner M, Colton T (1987): Health problems reported by residents of a neighborhood contaminated by a hazardous waste facility. Am J Ind Med 11:581–597.

Quanjer PH (1983): Clinical Respiratory Physiology. Standardized lung function testing. Bull Eur Physiopath Respir, Suppl 5, 19:7–64.

Rylander R, Andersson K, Belin L, Berglund G, Bergstrom R, Hanson L, Lundholm M, Mattsby I (1977): Studies on humans exposed to airborne sewage sludge. Schweiz Med Wochenschr 107: 182–184.

Scarlett-Kranz JM, Babish JG, Strickland D, Liski DJ (1987): Health among municipal sewage and water treatment workers. Toxicol Ind Health 3:311–319.

Sekla L, Gemmill D, Manfreda J, Lysyk M, Stackiw W, Kay C, Hopper C, Vanbuckenhout L, Eibisch G (1979): Sewage treatment workers and their environment. A health study. In Pahren H, Jakubowski W (eds): "Wastewater, Aerosols and Disease." Springfield, VA: Nat Techn Inf Serv, pp 281–294.

Sigsgaard T, Bach B, Maimros P (1990): Respiratory impairment among workers in a garbage-handling plant. Am J Ind Med 17:92–93.

Stanek EJ, Tuthill RW, Willis C, Moore GS (1987): Household hazardous waste in Massachusetts. Arch Environ Health 42:83–86.

World Health Organization (1986): "Early Detection of Occupational Diseases." Geneva.