CHEMICAL FIRE AT TOXIC WASTE DISPOSAL PLANT: EPIDEMIOLOGIC STUDY OF EXPOSURE TO SMOKE AND FUMES

William Halperin, M.D., Phillip J. Landrigan, M.D.,
Ronald Altman, M.D., Alfred W. Iaci, M.S.,
Dale L. Morese, M.D., Larry L. Needham, Ph.D.

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On December 8, 1977, a waste-chemical disposal plant in New Jersey exploded and burned. Among the chemicals combusted were polychlorinated biphenyls (PCB), which led to concern that PCB combustion might have produced tetrachlorodibenzofuran (TCDF) or tetrachlorodibenzodioxin (TCDD). To determine whether these products had formed and to evaluate the health effects of exposure to the fire, we conducted environmental and epidemiologic investigations.

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*/ This study was carried out by the Center for Disease Control, U.S. DHEW and the New Jersey State Department of Health, Division of Laboratories and Epidemiology. Dr. Halperin was affiliated with the Field Service Division, Bureau of Epidemiology and the Division of Surveillance, Hazard Evaluations and Field Studies. National Institute for Occupational Safety and Health. Center for Disease Control, Public Health Service, U.S. DHEW, Atlanta, Georgia, and with the Division of Laboratories and Epidemiology, New Jersey State Department of Health, Trenton. Dr. Altman and Mr. Iaci were members of the staff at the latter. Dr. Landrigan, Dr. Morse and Dr. Needham were affiliated with the Center for Disease Control. Correspondence may be addressed to Dr. Halperin, Industry-wide Studies Branch, National Institute for Occupational Safety and Health, 4676 Columbia Parkway, Cincinnati, Ohio 45226.

Industrial fires are commonplace --50,000 occurred in 1976 in industry, utilities, and defense establishments.[1] Toxic fumes from these fires are a health hazard both for firefighters who battle them as well as for nearby residents. In this paper we present results of an epidemiologic investigation of an unusual fire in a toxic waste disposal plant. This experience illustrates the need for toxicologic evaluation of complex industrial fires and emphasizes the need for providing firefighters with proper equipment and training in order to minimize adverse health effects of exposure to such fumes.

On December 8, 1977, a fire occurred at a waste-chemical disposal plant in New Jersey. Conditions at this fire exemplify many of the problems seen in modern industrial fires. The list of chemicals involved was long, and many of the commercial chemical products were not fully characterized; firefighters and health authorities became concerned about the toxicities of the chemicals and their combustion products only after the fire was quenched; access to the fire site was inadequately controlled; many firefighters and rescue workers were volunteers, inadequately trained and poorly equipped to fight industrial fires; finally, among the compounds in the fire were polychlorinated biphenyls (PCB), and the possibility existed, based on laboratory research,[2,3] that highly toxic tetrachlorodibenzofuran (TCDF) or tetrachlorodibenzodioxin (TCDD) might have formed in the combustion of PCB and might have contaminated persons at the fire, equipment or sorrounding communities.

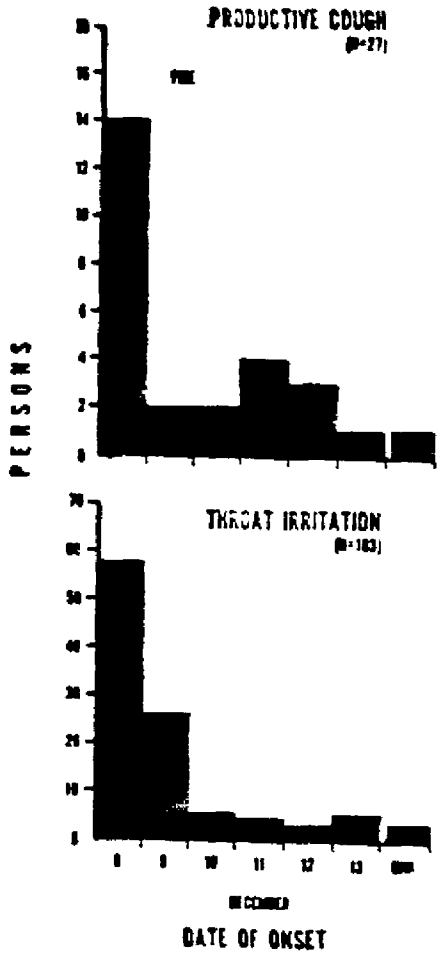
BACKGROUND

The toxic waste-disposal plant, located in rural southern New Jersey, consisted of tanks for the storage of industrial waste, high-temperature incinerators, and ancillary buildings. The stored waste contained a variety of substances such as PCB, benzene, methylene chloride, aniline and sludge. A series of explosions in storage tanks and fires began at about 2:30 p.m. on Thursday, December 8, 1977. Five workers died in the blaze, and one died subsequently of burns. During the fire, numerous company employees, first-aid units, police, volunteer fire companies, journalists and spectators, including a U.S. congressman, were present and had varied exposure to fumes and smoke.

Although many attendees developed symptoms during and after the fire, prompting a request on December 9 for public health evaluation of the significance of the fire for attendees and residents living nearby, it was not until later that day that a toxicologist reviewed the list of agents that had burned and suggested that combustion of the large volume of PCB solutions (greater than 15,000 gallons) may have produced TCDD or TCDF, highly toxic chemicals. TCDD is a contaminant in the manufacture of the herbicide 2,4,5-trichlorophenonxyacetic acid, a constituent of Agent Orange, and was the agent responsible for illness in Seveso, Italy,[4] when machinery at a plant manufacturing trichlorophenol as a feedstock for hechachlorophene malfunctioned.

Figure No. 1

DATE OF ONSET OF PRODUCTIVE COUGH OR THROAT IRRITATION



At that stage, officials of local, state, federal governments and agencies were faced with the following problems: the uncertainty as to whether TCDD or TCDF had been produced, the certainty that large numbers of attendees had been exposed to smoke and fumes and were symptomatic, the certainty that fire and rescue equipment had been contaminated by fire effluent, the possibility that a toxic plume may have contaminated a few residents nearby and, less likely, a greater number further away. Decisions were made to evacuate nearby residents, limit access to the fire site except to essentials, adequately protected personnel, identify individuals exposed during the fire and determine their health status, and conduct an environmental survey to determine the extent to TCDD or TCDF contamination, if any.

METHODS

Questionnaire Survey: We obtained names of persons at the fire by contacting fire companies, police, rescue squads, civil defense groups, and other groups who had participated, as well as by making a general appeal in the news media for exposed individuals. In the period December 11 to 14, a questionnaire (furnished on request by WH) was administered to exposed persons, either in small groups or individually by telephone.

Four hundred and forty (95.9%) of the 459 persons known to have been present at the fire were surveyed. On December 19, eleven days after the fire, a follow-up questionnaire was administered to 96 (91.4%) of the 105 persons who reported respiratory symptoms on the first questionnaire. On February 16, 54 days after the fire, 36 of the 37 persons (97.3%) who reported any residual symptoms on the second questionnaire were questioned a third time as to the persistence of their symptoms.

Environmental Survey: In collaboration with the New Jersey Department of Environmental Protection, the U.S. Environmental Protection Agency, and the U.S. Occupational Safety and Health Administration (OSHA), on December 10 we collected surface soil samples at points throughout the fire zone and at more distant control sites. Also, we obtained wipe samples with alcohol-impregnated sponges from the surfaces of firefighting equipment used at the fire.

Laboratory Methods: The soil and wipe samples were examined starting on December 10 by the Toxicology Branch, Clinical Chemistry Division, Bureau of Laboratories, Center for Disease Control for TCDD and for TCDF with use of gas chromatography and mass spectroscopy and with comparison against authenticated standards. Detection limits were 100 parts per billion (ppb) for TCDD and 10 ppb for TCDF.

RESULTS

Medical Survey Data: Two patterns of symptoms were found in the 440 persons whom we interviewed. The first symptom complex consisted of respiratory complaints and included throat irritation in 103 (23%), nonproductive cough in 77 (17%), chest pain in 54 (12%), shortness of breath in 42 (10%), productive cough in 27 (6%), and hemoptysis in 3 (0.7%). The second symptom complex was neurologic and usually occurred in persons who also manifested respiratory symptoms. The most frequent symptoms included headache in 161 (37%) and dizziness in 75 (17%). Other symptoms reported were eye irritation by 70 (16%) persons, nausea or vomiting by 64 (14%), and skin irritation by 59 (13%).

Onset of symptoms occurred primarily on the day of the fire and the day following, with only a small number of persons having onset in subsequent days (Figure 1). For most persons onset of symptoms occurred within five to ten hours after arrival at the fire.

An analysis of risk factors showed no statistically significant differences in symptom incidence between those persons closest to the fire site and those who had remained on the periphery. However, for those persons closest to the fire site, the incidence rates for six of twelve symptoms were associated possitively with duration of exposure (Table 1). For those who remained on the periphery, only dizziness was associated with length of exposure.

Analysis of symptom incidence rates by profession showed that firefighters had significantly more frequent throat irritation ($p < .01$), dry cough ($p < .05$), and chest pain ($p < .05$) than did persons in the other occupational categories. Workers employed at the chemical disposal plant had no significant excesses in the incidence of any symptoms and, indeed, had significantly lower rates than person in all other categories for headache, dizziness, eye irritation, and dry cough.

Age-specific attack rates were calculated to determine whether age had played a role in the occurrence of symptoms. No consistent gradients with age were observed, except that headache was significantly more frequent in persons under age 30 (40.2 percent) than in those 30 years old and above (20 percent) (x^2 22.44, $p < 0.001$).

There was no relationship noted between occurrence of symptoms and history of heart, lung, or other chronic disease or with smoking history.

Only 28 (6.4 percent) ofthe 440 persons exposed to the fire had used protective respirators. For those two occupational categories with highest frequency of respirator use (firemen and policemen), we

TABLE 1

SYMPTOM INCIDENCE RATES FOR PERSONS EXPOSED TO PLANT FIRE
BY DURATION OF EXPOSURE, NEW JERSEY, DECEMBER 8-9, 1977

Exposure Duration (hour)	Number of Persons	Percentage with Symptom					
		Dizziness	Chest Pain	Headache	Shortness of Breath	Dry Cough	Nausea or Vomiting
		(N=61)	(N=43)	(N=215)	(N=36)	(N=61)	(N=47)
2	117	10.2	4.3	28.2	5.1	9.4	7.7
2-6	143	23.8*	18.2*	46.8*	13.3*	25.2*	17.5*
6	62	24.2	19.3	40.3	17.7	22.6	21.0
TOTAL	322	18.9	13.3	38.8	11.2	18.9	14.6

* Z-statistic for exposure of less than two (2) hours v. exposure of 2-6 hours v. exposure 6 hours 1.96, p 0.05.
A statistically significant association was not seen for skin, eye, or throat irritation, hemoptysis, productive cough, or sleepiness.

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calculated attack rates for all symptoms for those persons who had used and those who had not used respirators. Generally, attack rates were higher for those who had used protection, a finding which may reflect their more intense exposure to the fire. Sleepiness ($p < 0.004$) was significantly more frequent in respirator users than in non-users.

Analysis of the persistence of symptoms showed that symptoms generally abated within one week after onset. A few persons, however, still exhibited symptoms after 60 days (Figure 2).

Laboratory Results: Analysis of surface soil and wipe samples at CDC by gas chromatography and mass spectroscopy showed no evidence of either TCDD or TCDF in any environmental sample.

Discussion: Firefighters and other persons at the disaster scene in shouthern New Jersey were exposed to smoke and fumes. Such exposure is evident not only by anecdote, but also from the frequent occurrence of smoke and fire-related symptoms that occurred in many persons present at the scene. Fortunately, these symptoms were not severe and generally not of long duration. This relative mildness resulted, however, less from any precautions taken at the fire than from the fortuitous absence of high concentrations of highly toxic fumes. Because of the complex mixture of chemicals present, it is impossible to say which specific exposures or exposure combinations resulted in the observed symptoms.

This disaster presented a particular dilemma to health and environmental authorities in that the possibility was raised soon after the fire that the extremely dangerous chemical toxicants TCDD or TCDF might have been produced in the conflagration. Attention thus had to be focused on several procedures:

1. rapid environmental sampling for TCDD and TCDF,

2. limitation of potential exposures after the fire while awaiting laboratory evaluations for the presence of TCDD and TCDF,

3. contingency planning for evacuation had these chemicals been present, and

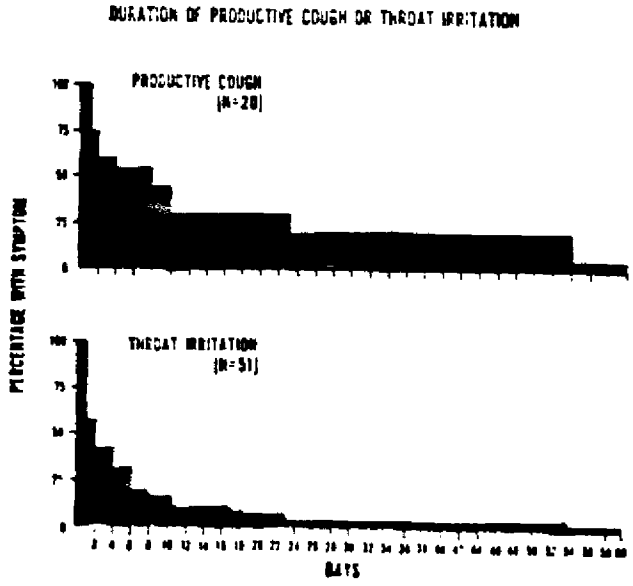
4. monitoring of persons present at the fire for the effects of exposure to these toxins.

Fortunately, neither of these highly toxic chemicals was found in this instance, and early restrictions were relaxed. However, the potential for the generation of these toxic chemicals under similar conditions has subsequently been reasserted.[5]

Disasters such as this fire are both a reminder of the continuing hazards of the workplace and a warning to civil officials to prepare for the large-scale chemical emergencies that may occur in modern industrial establishments.[4] We believe that officials familiar with human toxicology must be involved in the management of similar catastrophes in order to ensure that potential health hazards are considered and appropriately assessed.

Firefighting is perceived by firefighters as a hazardous occupation. "When a guy gets hurt at a fire, it's easier to remember the injury than the man's name. There are many names, but the injuries are all about the same -- a guy got burned, he fell through the roof or a floor, he got cut by falling glass, the ceiling or a wall fell on him, or he was overcome by heat or smoke. These injuries can't be prevented, not as long as the best way to put out a fire is to get close to it."[6] In fact, the risk of accidental death for firefighters is excessive, approximately 35 percent higher than for the general population. Firefighters are also at higher increased risk of acute and chronic work-related injuries. They lose pulmonary function at twice the expected rate, and this accelerated rate of loss is related significantly to frequency of fire exposure.[8] They suffer higher frequency of chronic obstructive lung disease.[9,10]

Figure 2



A peculiar modern threat to the health of firefighters is the hazard of exposure to toxic gases and fumes formed during combustion of chemical and plastic products.[11-14] Examples of toxic fumes involved in such exposures include hydrochloric acid fumes formed in the combustion of polyvinyl chloride[15] and combustion products of polytetrafluoroethylene, Teflon,* which may induce "polymer fume fever,"[16] and hydrogen cyanide, which may be formed in the burning of the acrylonitrile plastics,[12] used widely in the formation of pipe and floor tiles.

Firefighters should not be exposed unnecessarily to dangerous substances in firefighting. Exposure could be minimized through:

1. limiting the number of trained firefighters to those necessary to handle the fire and, even more importantly, of untrained ancillary personnel allowed at the fire scene,

2. using appropriate safety equipment for respiratory and cutaneous protection, and

3. having readily available to local authorities inventories of the chemicals and toxins present on industrial sites and of their potential combustion products.

Furthermore, regular and volunteer fire departments and rescue squads should be alerted to the particular consequences of fires in industries in their locales so that these personnel can be properly trained and equipped.

SUMMARY

On December 8, 1977, a waste-chemical disposal plant in New Jersey exploded and burned. Among the chemicals combusted were polychlorinated biphenyls (PCB), and there was concern that PCB combustion might have produced tetrachlorodibenzofuran (TCDF) or tetrachlorodibenzodioxin (TCDD). To determine whether these products had formed and to evaluate the health effects of exposure to the fire, we conducted environmental and epidemiologic investigations.

* Inclusion of trade name is for identification only and does not imply endorsement by the U.S. Public Health Service.

No TCDF or TCDD was detected in soil samples or in wipe samples of firefighting equipment; detection limits were 10 parts per billion (ppb) and 100 ppb, respectively, for TCDF and TCDD. Evaluation of 440 (96%) exposed persons showed that symptoms had developed in 270 (61%), usually within five to ten hours after arrival at the scene. Respiratory symptoms were most common and included throat irritation in 103 (23%), cough in 77 (17%), shortness of breath in 42 (10%), and pleuritic pain in 54 (12%). The highest incidence of respiratory symptoms was for firefighters. Incidence rates for six of twelve symptoms were associated with duration of exposure. Firefighters and other emergency workers should be trained and equipped to deal safely with toxins encountered at industrial fires.

REFERENCES

1. Derry L.: A study of United States fire experience. Fire Journal 71:50-53, 1977.

2. Morita M., Nakagawa J., Rappe C.: Polychlorinated dibenzofuran formed from PCB mixture by heat and oxygen. Bull Environm Contam Toxicol 19:665-670, 1978.

3. Buser H. R., Bosshardt H. P., Rappe C.: Formation of polychlorinated dibenzofurans from the pyrolysis of PCBs. Chemosphere I:109-119, 1978.

4. Fuller, J. G.: The Poison that Fell from the Sky. New York, Random House, 1977.

5. O'Rell M. K.: Fate of PCBs in Rollins Environmental Services plant fire. EPA Contract No. 68-02-2165. Washington: U.S. Environmental Protection Agency, 1978.

6. Smith D: Report from Engine Co. 82. New York, Pocket Books, 1973.

7. Musk, A. W., Monson, R. R., Peters, J. M., Peters, R. K.: Mortality among Boston Firefighters, 1915-1975. Br J Ind Med 35:104-108, 1978.

8. Peters J. M., Theriault G. P., Fine J. F., Wegman D.: Chronic Effect of Firefighting on Pulmonary Function. New England Journal of Medicine 291:1320-1322, 1974.

9. Loke, J., Matthay R. A., Farmer W. C., Rutman C. E.: Acuete and Chronic Effects of Firefighting on Pulmonary Function. American Review of Respiratory Diseases 4:247, 1978.

10. Musk, A. W., Peters J. M., Rubin C: Acute Changes in One-Second Forced Expiratory Volume in Firefighters and their Possible Relationship to Chronic Changes. American Review of Respiratory Diseases 41:25, 1978.

11. Axford A. T., McKerrow C.B., Parry Jones A., LeQuesne P. M.: Accidental Exposure to Isocyanate Fumes in a Group of Firemen. British Journal of Industrial Medicine 33:65-71, 1976.

12. Terrill J. B., Montgomery R. R., Reinhardt C. F.: Toxic Gases from Fires. Science 200:1343-1347, 1978.

13. Gold A, Burgess W. A., Clougherty E. V.: Exposure of Firefighters to Toxic Air Contaminants. American Industrial Hygiene Association Journal 39:534-539, 1978.

14. Smith T. J., Musk A. W., Gold A., Roto P.: Acute Respiratory Effects of a Fire Involving Silicone Rubber. Int. Arch. Occup. Environ. Health 41:139-145, 1978.

15. Dyer R. F., Escsh V. H.: Polyvinyl Chloride Toxicity in Fires: Hydrogen Chloride Toxicity in Firefighters. JAMA 234:393-397, 1972.

16. Eckardt R.: The Health Hazards of Plastics. J. Occup. Med. 15:808-819, 1973.