

HETA 91-073-2165
DECEMBER 1991
CARBONNAIRE COMPANY
PALMERTON, PENNSYLVANIA

NIOSH INVESTIGATORS:
JOHN DECKER, M.S.
STEVE GALSON, M.D.

I. SUMMARY

In January 1991, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation from a Carbonnaire Company representative to evaluate possible employee exposures to metal dusts, which reportedly blow through the Carbonnaire facility from an adjacent zinc recycling company. The Carbonnaire Company is a manufacturer of ammonia and carbon dioxide.

On February 26 and June 4, 1991, NIOSH investigators collected air samples, wipe samples, and soil samples for analysis of metal (including lead) content. Air concentrations of lead ranging from non-detected to 11 micrograms per cubic meter of air ($\mu\text{g}/\text{m}^3$). However, there was very little wind on both NIOSH visits. Wipe samples had lead concentrations ranging from 108 to 432 micrograms per square foot ($\mu\text{g}/\text{ft}^2$). Samples of surface soil and ventilation filter dust contained up to 4.5% lead.

On August 14, 1991, NIOSH investigators collected blood samples from 13 of 29 workers (45% of the staff) at the facility. Additional environmental sampling was also conducted. The concentrations of lead in the blood samples ranged from 4 to 13 micrograms per deciliter ($\mu\text{g}/\text{dl}$), all below 40 $\mu\text{g}/\text{dl}$, the level where the Occupational Safety and Health Administration (OSHA) standard on lead exposures requires action. The concentrations of zinc protoporphyrin (ZPP), a biochemical indicator of impaired heme synthesis and possible lead exposure, ranged from 15 to 46 $\mu\text{g}/\text{dl}$, all below 50 $\mu\text{g}/\text{dl}$, the upper limit of "normal." Airborne lead concentrations ranged from non-detected to 12 $\mu\text{g}/\text{m}^3$. Wind direction was from the west (down-wind of the zinc recycling plant) and ranged from 2.5 to 6 miles per hour.

Personal breathing-zone concentrations of ammonia ranged from 0.6 to 122.6 parts per million (ppm). The NIOSH Recommended Exposure Limit (REL) for ammonia (up to 10 hours/day, 40 hours/week) is 25 ppm, as a time-weighted average (TWA). The short-term exposure limit (STEL) is 35 ppm, over any 15 minute period. The highest personal exposure (122.6 ppm), collected over 5 minutes, occurred in the east compressor area during the June 1991 visit. Detector tube measurements ranged from <5 to 300 ppm ammonia. High ammonia concentrations resulted from leaking process equipment at Carbonnaire.

A health hazard exists from exposures to ammonia and a potential health hazard may exist from exposure to lead. Over-exposures to ammonia resulted from leaking equipment during the manufacture of ammonia. The presence of lead in surface soil and ventilation filter dust poses a potential risk for ingestion and inhalation of lead, especially during dry, windy conditions. Lead exposures may also occur by walking around and stirring up the soil. There were no identified sources of lead from Carbonnaire's in plant operation. A complete discussion of recommendations may be found in section VII of this report.

KEYWORDS: SIC 2873 (Ammonia manufacture), SIC 2813 (Industrial gas manufacture, carbon dioxide), ammonia, carbon dioxide, lead, zinc.

II. INTRODUCTION

In January 1991, a Carbonaire Company Representative requested a Health Hazard Evaluation (HHE) to evaluate possible employee exposures to metal dusts, which reportedly blow through their facility from an adjacent zinc recycling company. The request stated that an adjacent company had been recycling this dust for its zinc content (removal of lead, arsenic, cadmium and other impurities) since 1985. A number of symptoms, including metallic taste, weakness, digestive problems, itching eyes, and memory loss, were thought to be related to exposures to the dust.

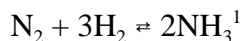
On February 26 and June 4, 1991, NIOSH investigators conducted industrial hygiene surveys of the Carbonaire facility, which included air sampling for metals and ammonia, collecting wipe and bulk samples, and conducting informal employee interviews. On August 15, 1991, NIOSH investigators returned to collect blood samples from employees and conduct additional air monitoring for lead.

III. BACKGROUND

Prior to the mid-1980s, the company adjacent to Carbonaire functioned as a zinc smelter. Since this time, the company has developed a process to reclaim electric arc furnace fume, which is a waste by-product from the steel industry. Although the primary recycled product is zinc, lead contamination of the electric arc fume is reportedly the primary hazard associated with the process.

The Carbonaire Company manufactures synthetic anhydrous ammonia by the Haber-Bosch process. Carbon dioxide (CO₂) is a by-product of the ammonia production. About 29 employees work over three shifts. The day shift operates between 7:00 a.m. and 3:00 p.m.

Ammonia (NH₃) is synthesized by the reaction between nitrogen (N₂) and hydrogen (H₂) in the presence of a catalyst.



The manufacturing process consists of three basic steps: gas-feed preparation, purification, and ammonia synthesis. The first two involve the production of hydrogen, introduction of nitrogen in a stoichiometric proportion, and the removal of catalytic poisons, such as carbon dioxide, carbon monoxide, and water vapor. Ammonia synthesis involves the catalytic fixation of nitrogen at specific temperatures and pressures.

The source of hydrogen is water and natural gas under elevated temperature and pressure. A by-product of the hydrogen-producing reaction is carbon monoxide, which is converted to carbon dioxide.¹

The final ammonia product is compressed, stored in large cylindrical spheres, and periodically transferred into rail cars. The carbon dioxide by-product is stored in large tanks for later loading into tanker trucks.

The Carbonaire Company is located 200-300 yards east (generally downwind) of the recycling company. The Carbonaire process facilities are not enclosed within a building (exceptions are the gas compressors and control room).

IV. EVALUATION DESIGN AND METHODS

A. Air Sampling for Metals

Area and personal breathing zone air samples for metal dusts were collected by drawing air through a 0.8 micron cellulose ester membrane filter at a flow rate of 2.0 liters per minute (lpm) using battery operated sampling pumps. On the February visit, four area samples and four personal samples were collected. On the June visit, one area and two personal samples were collected. During the August visit, three area samples and two personal samples were collected. Temperature, humidity, wind speed and wind direction were measured on each visit.

The samples were chemically digested and analyzed by inductively coupled argon plasma atomic emission spectroscopy (ICP/AES), according to NIOSH ICP Elements method 7300. The limits of detections (LODs) per sample for the analyzed elements may be found in Table 1.

B. Wipe Samples for Metals

During the February visit, six wipe samples were collected with Whatman® smear tabs moistened with water. While wearing disposable Ambi® vinyl gloves, the industrial hygienist wiped over a 15 X 15 centimeter (cm) area through a series of horizontal left-to-right strokes. The gloves were changed after each sample to prevent cross-contamination. Care was taken to use the same method and wiping pressure for each sample. The samples were placed in glass scintillation vials for transportation to the laboratory. Laboratory analysis of the samples was also performed according to the NIOSH ICP Elements method 7300.

Two wipe samples were collected from desk tops in the office trailer, one sample from a desk top in the control room, one sample from the surface of a gas compressor, one sample from a counter top in the CO₂ loading building, and one sample near the main air in-take for the ammonia process.

The quantities of dust collected by wiping over a 15 X 15 centimeter (cm) area were mathematically converted to micrograms (µg) per square foot (ft²) surface area. The LODs per Whatman® smear tab sample are listed in Table 1.

C. Bulk Soil and Dust Samples for Metals

Bulk samples of surface soil were collected with disposable plastic spoons by scraping or scooping approximately 1 gram of material into a scintillation vial.

During the February visit, one bulk sample of furnace filter dust and one soil sample from the southwest edge of the property was collected and analyzed for metals. In June, five additional soil samples were collected from various locations on the property. One sample of furnace filter dust was again collected from the furnace filter in the office trailer.

A weighed portion of each sample was chemically digested and analyzed for metals according to NIOSH method 7300. The results are presented in terms of percent composition (LODs listed in Table 1).

D. *Blood Samples*

All workers present were offered the opportunity to provide a blood sample for measurement of blood lead levels (BLL) and zinc protoporphyrins (ZPP). Blood samples were collected from 13 of 29 workers (45% of the staff) at the facility. Workers from all job categories and shifts were represented.

E. *Ammonia Sampling*

Five personal breathing zone samples and two area samples for ammonia were collected during the June visit. Using battery operated sampling pumps, the samples were collected by drawing air through sulfuric acid-treated silica gel tubes (SKC 226-10-06, lot 641) at a flow rate of 0.10 lpm. Full-shift personal breathing zone samples were collected from a compressor person, an operator, and a supervisor. Two short-term samples were collected from the ammonia loader, and one short-term sample was collected from a compressor person. One area sample was collected near the east compressor. The Limit of Detection (LOD) and Limit of Quantitation (LOQ) for the ammonia samples were 0.5 and 1.6 µg/sample, respectively.

Area concentrations of ammonia were also determined with Draeger® 5/a colorimetric detector tubes throughout the facility on both NIOSH visits. The standard range of measurement is 5 to 70 parts per million (ppm) ammonia, but can be extended up to 700 ppm. Eight measurements were recorded in February, and six measurements were recorded during the June visit.

V. **EVALUATION CRITERIA**

A. *General Guidelines*

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours/day, 40 hours/week for a working lifetime without experiencing adverse health effects. It is important to note, however, that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A

small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the limits set by the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus the overall exposure may be increased above measured airborne concentrations. Evaluation criteria typically change over time as new information on the toxic effects of an agent become available.

The primary sources of evaluation criteria for the workplace are the following: NIOSH Criteria Documents and Recommended Exposure Limits (RELs),² the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs),³ and the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).⁴ These values are usually based on a time-weighted average (TWA) exposure, which refers to the average airborne concentration of a substance over the entire 8- to 10-hour workday. Concentrations are usually expressed in parts per million (ppm) or milligrams per cubic meter (mg/m³). In addition, for some substances there are short-term exposure limits (STELs) or ceiling limits which are intended to supplement the TWA limits where there are recognized toxic effects from short-term exposures.

The OSHA standards are required to take into account the feasibility of reducing exposures in various industries where the agents are used; whereas the NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. In evaluating worker exposure levels and NIOSH recommendations for reducing exposures, it should be noted that employers are legally required to meet the requirements of OSHA PELs and other standards. The evaluation criteria for a number of metals and ammonia are presented in Table 2.

B. *Specific Substances*

1. **Lead**

Toxicology Inhalation (breathing) of lead dust and fume is the major route of lead exposure in industry. Another source of exposure is ingestion (swallowing) resulting from hand-to-mouth contact with lead-contaminated food, cigarettes, clothing, or other objects. Once absorbed, lead is excreted from the body very slowly. Absorbed lead can damage the kidneys, gastrointestinal tract, peripheral and central nervous systems, and the blood-forming organs (bone marrow). Effects include weakness, tiredness, irritability, constipation, anorexia, abdominal discomfort, "lead colic," anemia, high blood pressure, kidney damage, cognitive (thinking) impairment, anxiety, depression, forgetfulness, and slowed reaction times. Chronic lead exposure is associated with infertility in both sexes and with fetal damage in pregnant women.^{5,6,7}

Lead has been shown to cause chronic kidney disease in workers with a lengthy occupational exposure to lead.⁸ The process is gradual and dose-related. Because the kidney has an enormous reserve capacity, results of renal function tests, e.g., blood urea nitrogen (BUN), serum creatinine, and serum uric acid, will not be abnormal until one-third to one-half of kidney function has been compromised.⁹

Lead is a trace element in foods and beverages. Adults consume approximately 300 µg of lead each day of which only approximately 10% is absorbed, while children absorb nearly 50% of ingested lead. The daily respiratory intake for adults living in the United States is 20 µg.^{10,11} In non-industrial environments, the greatest single source of lead in air has been from automobile exhaust, but this source has essentially been eliminated in the United States.¹²

Previous studies report that overt symptoms of lead poisoning in adults generally begin at blood lead levels (BLLs) between 60 and 120 µg/dl.¹⁰ Lead-acid battery workers, who may be heavily exposed to lead, have been shown to be at higher risk of dying from cerebrovascular and renal disease.^{10,11} Neurologic, hematologic, and reproductive effects, however, may be detectable at much lower levels, and the World Health Organization (WHO) has recommended an upper limit of 40 µg/dl for adult males.¹³ Recent studies suggest that exposure of the developing fetus to BLLs far below these occupational exposure limits is associated with subtle neurologic impairment in early life and that there may not be a safe threshold for this effect.^{14,15} The mean serum lead level for U.S. men between 1976 and 1980 was 16 µg/dl,^{16,17} however, with the implementation of lead-free gasoline and reduced lead in food, the 1991 average serum lead level of U.S. men will probably drop below 9 µg/dl.¹⁸

OSHA Lead Standard and Blood Lead Levels The OSHA general industry Lead Standard (29 CFR 1910.1025) specifies a PEL for airborne lead of 50 micrograms per cubic meter (µg/m³) calculated as an 8-hour TWA for daily exposure.⁴ The regulation also requires semi-annual monitoring of blood lead for employees exposed to 30 µg/m³ or greater of lead. Employees whose BLL is 40 µg/dl or greater must be retested every two months. Medical removal of employees is required when an employee's BLL averages 50 µg/dl or greater over a six month period. A BLL of 60 µg/dl or greater, confirmed by retesting within 2 weeks, is an indication for immediate removal.¹⁹

The zinc protoporphyrin (ZPP) level is a measure of lead interference with hemoglobin production. Heme synthetase is the last enzyme in heme synthesis. Although some diseases and iron deficiency can cause a rise in ZPP, in a healthy individual working with lead, exposure to lead is the most likely cause for such an increase. ZPP levels begin to increase as BLLs reach 14-17 µg/dl and tend to stay elevated for 3-4 months (the average life span of a red cell). Normal values are below 50 µg/dl.¹⁶

Lead in Settled Dust There are no specific criteria for the workplace governing the concentration of lead in settled dust. The states of Maryland

and Massachusetts have established standards for dust on specific interior surfaces of residential dwellings.²⁰

Floors: 200 $\mu\text{g}/\text{ft}^2$
Window Sills: 500 $\mu\text{g}/\text{ft}^2$
Window Wells: 800 $\mu\text{g}/\text{ft}^2$

These standards were intended to prevent lead poisoning in children, which can result from ingestion of the dust or lead-containing paint chips or from chewing on window sills or other protruding surfaces having lead-containing paint. These standards are of little relevance to industrial settings.

Lead in Soil There are no specific criteria for lead concentrations in soil. 40 CFR 260.10 of the Resource Conservation and Recovery Act (RCRA); however, specifies the characteristics of a substance which would classify it as a hazardous waste. Other EPA regulations specify the definition of a hazardous substance, which could include lead-containing soil. The regulations do not specify a concentration of lead in soil that would cause it to be classified as a hazardous substance or waste.

The Environmental Protection Agency (EPA) has set forth a directive for a soil cleanup when the total lead level is 500 to 1000 ppm, which the Office of Emergency and Remedial Response and the Office of Waste Programs Enforcement considers protective for direct contact at residential settings.²¹

2. **Zinc Oxide**

The occupational exposures of principal concern are those to *freshly* formed zinc oxide fume produced by subjecting zinc or some of its compounds to high temperatures. Inhalation of fumes may result in dryness and irritation of the throat, a sweet or metallic taste, chest tightness, cough, and an influenza-like illness called *metal fume fever*. Metal fume fever develops several hours following exposure and consists of chills, fatigue, malaise, headache, back pain, muscle cramps, and occasionally, blurred vision, nausea, and vomiting. These symptoms usually subside after 6 to 12 hours, but may last for up to 24 hours; recovery is usually complete. Symptoms have been reported in workers from exposure to concentrations of fume below 5 mg/m^3 . Zinc oxide dust is considered a nuisance dust without significant adverse effects at reasonable exposure levels.²²

3. **Ammonia**

Ammonia is a severe irritant of the eyes, respiratory tract, and skin. Exposure to high concentrations (2500-6500 ppm) causes severe corneal irritation, shortness of breath, bronchospasm, chest pain, and pulmonary edema, and may be fatal. Exposure to 134 ppm in one study caused irritation of the eyes, nose, and throat in most subjects and one person complained of chest irritation. Surveys of workers have generally found that the maximal concentration not resulting in significant complaints is 20

to 25 ppm. Repeated exposure to ammonia gas may cause chronic irritation of the eyes and upper respiratory tract.^{22,23}

VI. RESULTS AND DISCUSSION

During the February and June 1991 NIOSH visits, the winds were calm. Emissions from the recycling company, moving away from Carbonnaire, could be seen during the February NIOSH visit. During the August 1991 NIOSH visit, the wind direction was to the east (down-wind of the zinc recycling plant) and wind speed ranged from 2.5 to 6 miles per hour.

A. *Air Monitoring for Metals*

Lead Personal breathing zone samples (all visits) for lead ranged from non-detected to $7 \mu\text{g}/\text{m}^3$, well under the OSHA PEL of $50 \mu\text{g}/\text{m}^3$. The measured air levels may have resulted from disturbing lead-containing soil as the workers walked about the facility. Since lead concentrations in the soil may contribute to lead exposure, increased exposures may occur when the soil is very dry and the wind is blowing strongly. The highest area sample concentrations for lead (11 and $12 \mu\text{g}/\text{m}^3$) were found in the office trailer (secretary's office) and CO_2 loading area, respectively. The specific sampling results may be found in Tables 3 and 4.

Other Metals Low concentrations of calcium, iron, manganese, and zinc were detected on both NIOSH visits. The levels found were substantially below all occupational evaluation criteria and are not thought to present a health hazard.

B. *Wipe Samples for Metals*

The wipe sample results, which are only semi-quantitative, indicated notable concentrations of lead in all locations tested. Concentrations ranged from $108 \mu\text{g}/\text{ft}^2$ on one of the office trailer's desks to $432 \mu\text{g}/\text{ft}^2$ on a surface of a gas compressor. Wipe sample results can be found in Table 5.

C. *Bulk Samples for Metals*

Dust from the office trailer's furnace filter, collected in February 1991, contained 4.5% lead. A sample collected in June 1991, contained 1.7% lead. A new furnace filter was installed in February and remained in place until the June visit. The presence of lead in the furnace filter indicates that airborne dusts containing lead are periodically present at Carbonnaire. Both filter dust samples contained 18.0% zinc. The presence of lead, however, is toxicologically more important than zinc. The zinc dust would not be toxicologically equivalent to freshly formed zinc fume particulate.

Notable lead concentrations in the soil samples, ranging from 0.25% (2500 ppm) to 1.7% (17,000 ppm), were found on the Carbonnaire property. Specific results can be found in Tables 6 and 7.

D. *Blood Lead Levels and Zinc Protoporphyrins*

The concentrations of lead in the blood samples ranged from 4 to $13 \mu\text{g}/\text{dl}$, all below $40 \mu\text{g}/\text{dl}$, the level where the OSHA standard on lead exposures requires action. These results are within the range expected for the general population.

The concentrations of zinc protoporphyrins in the blood samples ranged from 15 to 46 µg/dl, all within the normal range.

E. *Air Monitoring for Ammonia*

During the June 1991 visit, personal breathing zone exposures to ammonia, including two full-shift samples, ranged from 0.6 to 122 ppm. The highest exposure (122 ppm) was a 5-minute sample collected from an employee working in the east compressor area. The short-term criteria for ammonia is a 15-minute short-term exposure limit (STEL) of 35 ppm. If no exposure was assumed for the remaining 10 minutes, the time-weighted average (TWA) would still be in excess of the STEL (40.8 ppm). An area sample also indicated a high concentration of ammonia in the vicinity, emanating from the compressor. The samples were collected on sulfuric acid-treated silica gel tubes and sent to a laboratory for analysis. The specific results can be found in Table 8.

During the February 1991 visit, ammonia concentrations, measured with detector tubes, ranged from <5 to 300 ppm. The highest concentrations (95 to 300 ppm) were measured near the ammonia storage spheres, where ammonia was obviously leaking. Instantaneous concentrations in the east compressor area were about 30 ppm. Specific results can be found in Table 9.

During the June 1991 visit, the company reported that the equipment in the ammonia sphere area had been repaired. Concentrations in the area were below the detector tube's range of measurement (5 ppm). This was a dramatic improvement from the February visit, when concentrations ranged from 95 to 300 ppm. Concentrations in the east compressor area ranged from 30 to 250 ppm, depending on the flow of wind through the partially enclosed area. The concentration between the two central compressors was measured at 35 ppm. Specific results can be found in Table 10.

F. *Interviews*

Four out of eight first-shift employees reported various symptoms, which they attributed to the work environment. One person reported headaches, three reported eye irritation, two reported nausea or digestive disturbances, three reported unusual or metallic taste, and one reported allergic type symptoms. One person reported irritability and forgetfulness.

Two of the four employees reporting symptoms also had blood lead and zinc protoporphyrins measured. Since these parameters were within accepted ranges, the reported symptoms are probably not related to lead exposures.

The eye irritation may be related to ammonia exposure, even at the relatively low concentrations measured. Although metallic taste and digestive disturbances might suggest exposure to *fresh* zinc oxide fume, exposure to fumes emitted by the stack of the neighboring plant, at the concentrations measured and distance from the source, would not be expected to cause these symptoms.

VII. RECOMMENDATIONS

A. Lead

Soil samples and dust samples from furnace filters indicate that the entire Carbonnaire facility is contaminated with lead. It should be noted, however, that air sampling and blood analysis did not indicate excessive exposures to lead. Usually, engineering controls are the initial, preferable method for controlling potential workplace exposures to harmful substances. Engineering controls are generally intended to control contaminants at their source. At Carbonnaire, the source of potential lead exposure is apparently the soil and lead-contaminated dust blowing through the air and settling in the soil. Elimination of potential exposures to lead would require environmental cleanup of the site and elimination of any further contamination. However, in the interim, the following work practice controls are offered as prudent measures to reduce potential exposures to lead.

Good personal hygiene practices can contribute to the control of worker exposure to lead. In addition, workers need to understand the potential for exposing family members to lead brought home on clothing, shoes, hair, etc.

1. Workers should wash hands and face before eating, drinking, or smoking.
2. Workers should have designated changing and shower areas to avoid cross-contamination of street and work clothes. The employer should provide for the cleaning and laundering of work clothing and equipment.
3. Airborne lead concentrations should be measured during extremely windy, dry conditions to determine if respiratory protection is needed under these environmental conditions. If respirators are required (concentrations above the OSHA PEL of $50 \mu\text{g}/\text{m}^3$), a respirator program that complies with the OSHA respiratory protection standard 29 CFR 1910.134 and the *NIOSH Guide to Industrial Respiratory Protection* should be implemented. If air monitoring indicates concentrations in excess of the OSHA PEL, respirators should be required on *any* windy, dry day.

B. Ammonia

High concentrations of ammonia, originating from leaking or defective equipment at Carbonnaire, were measured on both NIOSH visits.

Over-exposures to ammonia are a health hazard to workers at the Carbonnaire Company. If leaking equipment is found, repairs should be made to stop the leaks. In the interim, workers should wear full face-piece air-purifying respirators when entering areas (such as the east compressor area) where air concentrations could exceed 35 ppm. Workers who repair leaking equipment should wear supplied-air respirators. A formal respirator program, as explained previously, should be implemented if workers will be using respirators.

If further evaluation or technical expertise is needed, a list of industrial hygiene ventilation consultants who are members of the American Industrial Hygiene Association (AIHA) is available from the following address:

American Industrial Hygiene Association
345 White Pond Drive
Akron, Ohio 44311-1087

VIII. REFERENCES

1. Kirk-Othmer, ed. [1978]. Encyclopedia of chemical technology. 3rd ed., Vol. 4. John Wiley & Sons, New York, pp. 478-482.
2. CDC [1988]. NIOSH recommendations for occupational safety and health standards 1988. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. MMWR 37 (supp S-7).
3. ACGIH [1990]. Threshold limit values and biological exposure indices for 1990-1991. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.
4. Code of Federal Regulations [1989]. Air contaminants--permissible exposure limits. 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.
5. Hernberg, S., et al [1988]. Lead and its compounds-- in occupational medicine 2nd ed. Chicago: Year Book Medical Publishers, pp. 457-582.
6. Landrigan, P, et al. [1985]. Body lead burden: summary of epidemiological data on its relation to environmental sources and toxic effects. In: Dietary and environmental lead: human health effects. Amsterdam: Elsevier Science Publishers.
7. Proctor N, Hughes J, and Frischman M [1988]. Chemical hazards in the workplace. 2nd ed., New York: Lippincott, pp. 294-298.
8. Weeden R, et al. [1975]. Occupational lead nephropathy. Am J Med. 59:630.
9. Page L and Culver P [1962]. A syllabus of laboratory examinations in clinical diagnosis. Cambridge: Harvard University Press.
10. Hernberg S, Dodson WN, and Zenz C [1980]. Lead and its compounds. In: Zenz C, Occupational Medicine. 2nd Ed. Chicago: Year Book Medical Publishers, pp. 547-582.
11. Landrigan PJ, Froines JR, Mahaffey KR [1980]. Body lead burden: summary of epidemiological data on its relation to environmental sources and toxic effects. Chapter 2. In Mahaffey KR (ed.): Dietary and environmental sources and toxic effects. Amsterdam: Elsevier Science Publishers.
12. ATSDR [1990]. Toxicological profile for lead. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry. DHHS (ATSDR) Publication No. TP-88/17.

13. World Health Organization [1980]. Recommended health-based limits in occupational exposure to heavy metals. Geneva: Technical Report Series 647.
14. Bellinger D, Levitan A, Waterman C, Needleman H, Rabinowitz M. [1988]. Longitudinal analyses of prenatal and postnatal lead exposure and early cognitive development. *New Eng J Med* 316:468-475
15. McMichael AJ, Bagnurst PA, Wigg NR, et al [1987]. Port Pirire cohort study: environmental exposure to lead and children's abilities at the age of four years. *New Eng J Med.* 316:1027-1043.
16. Muhaffey K, Annet J, Roberts J, Murphy R [1982]. National estimates of blood lead levels. United States, 1976-1980. *New Engl J Med* 307:373-9.
17. Annet J, Dirkle J, Makuc C, Nesse J, Bayse D, Kovar M [1983]. Chronological trends in blood lead levels between 1976 and 1980. *New Engl J Med* 308:1373-7.
18. CDC [1991]. Strategic plan for the elimination of childhood lead poisoning. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control.
19. Code of federal Regulations [1978]. OSHA: Occupational exposure to lead - final standard 29 CFR 1910.1025. Washington, DC: U.S. Government Printing Office, Federal Register.
20. HUD [1990]. Lead-based paint: interim guidelines for hazard identification and abatement in public and Indian housing. Office of Public and Indian Housing, Department of Housing and Urban Development.
21. EPA [1989]. Memorandum, OSWER Directive #9355.4-02, Interim guidance on establishing oil lead cleanup levels at superfund sites. Office of Solid Waste and Emergency Response, United States Environmental Protection Agency, September 7, 1989.
22. Proctor N, Hughes J, and Frischman M [1988]. Chemical hazards in the workplace. 2nd ed., New York: Lippincott, pp. 514-517.
23. NIOSH [1988]. Occupational health guidelines for chemical hazards-- Occupational Health Guideline for Ammonia. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 88-118.

IX. AUTHORSHIP AND ACKNOWLEDGEMENTS

Report Prepared by: John Decker, M.S.
Industrial Hygienist
Industrial Hygiene Section
Hazard Evaluations and Technical
Assistance Branch
Division of Surveillance, Hazard
Evaluations and Field Studies

Field Assistance: David Lewis, M.D.
Medical Officer
Medical Section
Hazard Evaluations and Technical
Assistance Branch
Division of Surveillance, Hazard
Evaluations and Field Studies

Lori Abrams
Industrial Hygienist
Industrial Hygiene Section
Hazard Evaluations and Technical
Assistance Branch
Division of Surveillance, Hazard
Evaluations and Field Studies

Originating Office: Hazard Evaluations and Technical
Assistance Branch
Division of Surveillance, Hazard
Evaluations and Field Studies

X. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report may be freely reproduced and are not copyrighted. Single copies of this report will be available for a period of 90 days after the date of this report from the NIOSH Publications Office, 4676 Columbia Parkway, Cincinnati, OH 45226. To expedite your request, include a self-addressed mailing label along with your written request. After this time, copies may be purchased from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161. Information regarding the NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address.

Copies of this report have been sent to:

1. Carbonaire Company
2. Teamster Local 773
3. Occupational Safety and Health Administration, Region III
4. Agency for Toxic Substances and Disease Registry (Philadelphia Office)

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

Table 1
 Carbonaire Co., Inc.
 Palmerton, Pennsylvania
 HETA 91-073
 Limits of Detection (LOD)

| Element | Air Samples, $\mu\text{g}/\text{sample}$ | Wipe Samples, $\mu\text{g}/\text{wipe}$ | Bulk Samples, LOD expressed as percent, based on 1 gram sample |
|-------------|---|--|---|
| Aluminum | 10 | 10 | 0.001 |
| Arsenic | 5 | 5 | 0.0005 |
| Barium | 1 | 1 | 0.0001 |
| Beryllium | 1 | 1 | 0.0001 |
| Calcium | 5 | 5 | 0.0005 |
| Cadmium | 1 | 1 | 0.0001 |
| Cobalt | 1 | 1 | 0.0001 |
| Chromium | 1 | 1 | 0.0001 |
| Copper | 1 | 1 | 0.0002 |
| Iron | 1 | 1 | 0.0001 |
| Lithium | 5 | 5 | 0.0001 |
| Magnesium | 2 | 5 | 0.0005 |
| Mangansese | 1 | 1 | 0.0002 |
| Molybdenum | 1 | 1 | 0.0001 |
| Nickel | 1 | 1 | 0.0001 |
| Lead | 2 | 2 | 0.0001 |
| Phosphorous | 10 | 10 | 0.0001 |
| Platinum | 10 | 10 | 0.001 |
| Selenium | 10 | 10 | 0.001 |
| Silver | 1 | 1 | 0.001 |
| Sodium | 20 | 20 | 0.0001 |
| Tin | 10 | 10 | 0.002 |
| Tellurium | 10 | 10 | 0.01 |
| Thallium | 10 | 10 | 0.006 |
| Titanium | 10 | 1 | 0.0001 |
| Tungsten | 10 | 10 | 0.001 |
| Vanadium | 1 | 1 | 0.0002 |
| Ytterium | 1 | 1 | 0.002 |
| Zinc | 1 | 1 | 0.0001 |
| Zirconium | 10 | 10 | 0.001 |

μg = microgram

Table 2
 Carbonaire Co., Inc.
 Palmerton, Pennsylvania
 HETA 91-073
 Evaluation Criteria

| Substance | | | NIOSH REL | OSHA PEL | ACGIH TLV |
|----------------------------------|----------------------------|------|-----------|----------|-----------|
| Ammonia | (ppm) | TWA | 25 | NC | 25 |
| | | STEL | 35 | 35 | 35 |
| Lead | $(\mu\text{g}/\text{m}^3)$ | TWA | NC | 50 | 150 |
| | | STEL | NC | NC | NC |
| Zinc oxide Dust | $(\mu\text{g}/\text{m}^3)$ | TWA | 5000 | 10000 | 10000 |
| | | STEL | NC | NC | NC |
| | | C | 15000 | NC | NC |
| Zinc Oxide Fume | $(\mu\text{g}/\text{m}^3)$ | TWA | 5000 | 5000 | 5000 |
| | | STEL | 10000 | 10000 | 10000 |
| Iron Oxide (as Fe) | $(\mu\text{g}/\text{m}^3)$ | TWA | 5000 | 10000 | 5000 |
| | | STEL | NC | NC | NC |
| Manganese dust & compounds | $(\mu\text{g}/\text{m}^3)$ | TWA | 1000 | NC | 5000 |
| | | STEL | 3000 | NC | NC |
| | | C | NC | 5000 | NC |

OSHA = Occupational Safety and Health Administration
 ACGIH = American Conference of Governmental Industrial Hygienists
 ppm = parts per million
 $\mu\text{g}/\text{m}^3$ = micrograms per cubic meter
 TWA = Time-Weighted Average
 STEL = Short-Term Exposure Limit
 C = Ceiling, 10 minute (NIOSH)
 REL = NIOSH Recommended Exposure Limit, 10 hour TWA
 PEL = OSHA Permissible Exposure Limit, 8 hour TWA
 TLV = ACGIH Threshold Limit Value, 8 hour TWA
 NC = No Criteria

TABLE 3
 Carbonaire Co., Inc.
 Palmerton, Pennsylvania
 HETA 91-073

Personal and Area Air Samples for Metals¹
 February 26, 1991

| Job Title | Location | Sample Period | TWA ² Concentration ($\mu\text{g}/\text{m}^3$) | | | | |
|----------------|------------------------------|---------------|---|----|----|----|-----------------|
| | | | Ca | Fe | Mn | Pb | Zn ³ |
| Compressor Man | Ammonia Compressors | 0655 - 1418 | 23 | 17 | 2 | 4 | 38 |
| Field Man | Throughout entire plant | 0658 - 1406 | 28 | 21 | 2 | 6 | 40 |
| Operator | Throughout entire plant | 0700 - 1418 | 26 | 26 | 2 | 6 | 47 |
| Loader | CO ₂ Loading Area | 0705 - 1050 | ND ⁴ | 10 | ND | ND | 24 |
| Area Sample | CO ₂ Loading | 0714 - 1446 | ND | 4 | ND | ND | 19 |
| Area Sample | NH ₃ Spheres | 0710 - 1444 | ND | 3 | ND | ND | 16 |
| Area Sample | Office ⁵ | 0745 - 1432 | 18 | 18 | 2 | 11 | 62 |
| Area Sample | Compressor ⁶ | 0740 - 1435 | 7 | 4 | ND | ND | 8 |

The samples were analyzed for the following minerals and metals: Aluminum, arsenic, barium, beryllium, calcium, cadmium, cobalt, chromium, copper, iron, lithium, magnesium, manganese, molybdenum, nickel, lead, phosphorous, platinum, selenium, silver, sodium, tin, tellurium, thallium, titanium, tungsten, vanadium, yttrium, zinc, and zirconium. Elements not listed were below the limit of detection.

² TWA: Time-weighted average concentration over the actual sampling period.

³ Total zinc (both fume and dust).

⁴ ND: Not detected (below the analytical limit of detection).

⁵ Secretary's office in office trailer.

⁶ Southwest area of ammonia compressors.

TABLE 4
 Carbonaire Co., Inc.
 Palmerton, Pennsylvania
 HETA 91-073

Personal and Area Air Samples for Metals¹
 June 4, 1991

| Job Title | Location | Sample Period | TWA ² Concentration ($\mu\text{g}/\text{m}^3$) | | | | |
|-----------|-----------------------|---------------|---|----|----|-----------------|-----------------|
| | | | Ca | Fe | Mn | Pb | Zn ³ |
| Repairman | Various | 0714-1430 | 16 | 35 | 3 | 7 | 71 |
| | Secretary's office | 0730-1434 | 12 | 14 | 1 | ND ⁴ | 3 |
| | West Edge of property | 0718-1415 | ND | 2 | ND | 7 | 38 |

Personal and Area Air Samples for Metals
 August 14, 1991

| | | | | | | | |
|------------------------------|---------|-----------|----|----|----|----|----|
| Shift Operator | Various | 1440-2209 | 15 | 17 | 2 | 6 | 41 |
| Field Operator | Various | 1442-2209 | ND | 3 | ND | ND | 11 |
| CO ₂ Loading Area | | 1407-2200 | 17 | 30 | 3 | 12 | 78 |
| NH ₃ Loading Area | | 1410-2159 | 8 | 12 | 1 | 5 | 27 |
| West Compressor Area | | 1422-2203 | 5 | 7 | 1 | 3 | 22 |

¹ The samples were analyzed for the following minerals and metals: Aluminum, arsenic, barium, beryllium, calcium, cadmium, cobalt, chromium, copper, iron, lithium, magnesium, manganese, molybdenum, nickel, lead, phosphorous, platinum, selenium, silver, sodium, tin, tellurium, thallium, titanium, tungsten, vanadium, yttrium, zinc, and zirconium. Other elements not listed were extremely low or below the limit of detection.

² TWA: Time-weighted average concentration over the actual sampling period.

³ Total zinc (both fume and dust).

ND = Below the limit of detection.

TABLE 5
 Carbonaire Co., Inc.
 Palmerton, Pennsylvania
 HETA 91-073

Wipe Samples for Metals
 February 26, 1991

| Element | Levels converted to $\mu\text{g}/\text{ft}^2$ | | | |
|-------------|---|---------------------|-----------------|-------------------------------|
| | Office (Secretary) | Office (Meining) | Control Room | NH ₃ Compressor |
| Aluminum | ** | ** | ** | 90 |
| Arsenic | ** | ** | ** | ** |
| Barium | ** | ** | ** | ** |
| Beryllium | ** | ** | ** | ** |
| Calcium | 405 | 198 | 774 | 864 |
| Cadmium | 9 | 18 | ** | 18 |
| Cobalt | ** | ** | ** | ** |
| Chromium | ** | ** | ** | 9 |
| Copper | 18 | 9 | 18 | 36 |
| Iron | 423 | 225 | 603 | 2070 |
| Lithium | ** | ** | ** | ** |
| Magnesium | 36 | ** | 63 | 144 |
| Manganese | 54 | 27 | 72 | 216 |
| Molybdenum | ** | ** | ** | ** |
| Nickel | ** | ** | 9 | ** |
| Lead | 216 | 108 | 135 | 432 |
| Phosphorous | ** | ** | ** | ** |
| Platinum | ** | ** | ** | ** |
| Selenium | ** | ** | ** | ** |
| Silver | ** | ** | ** | ** |
| Sodium | 360 | 180 | 450 | 450 |
| Tin | ** | ** | ** | ** |
| Tellurium | ** | ** | ** | ** |
| Thallium | ** | ** | ** | ** |
| Titanium | ** | ** | ** | ** |
| Tungsten | ** | ** | ** | ** |
| Vanadium | ** | ** | ** | ** |
| Ytterium | ** | ** | ** | ** |
| Zinc | 1080 | 1080 | 1170 | 3780 |
| Zirconium | ** | ** | ** | ** |

** Signifies that the amount of this element was below the analytical limit of detection.

TABLE 5 (continued)
 Carbonaire Co., Inc.
 Palmerton, Pennsylvania
 HETA 91-073

Wipe Samples for Metals
 February 26, 1991

| Levels converted to $\mu\text{g}/\text{ft}^2$ | | |
|---|---|---|
| | CO ₂ Loading Building (counter top) | Underside of Steel Structure (near air intake for process) |
| Aluminum | 90 | ** |
| Arsenic | ** | ** |
| Barium | ** | ** |
| Beryllium | ** | ** |
| Calcium | 765 | 261 |
| Cadmium | 18 | ** |
| Cobalt | 9 | ** |
| Chromium | 9 | ** |
| Copper | 27 | 18 |
| Iron | 1710 | 729 |
| Lithium | ** | ** |
| Magnesium | 126 | 63 |
| Manganese | 171 | 81 |
| Molybdenum | ** | ** |
| Nickel | 27 | ** |
| Lead | 405 | 297 |
| Phosphorous | ** | ** |
| Platinum | ** | ** |
| Selenium | ** | ** |
| Silver | ** | ** |
| Sodium | 540 | 459 |
| Tin | ** | ** |
| Tellurium | ** | ** |
| Thallium | ** | ** |
| Titanium | ** | ** |
| Tungsten | ** | ** |
| Vanadium | ** | ** |
| Ytterium | ** | ** |
| Zinc | 2700 | 1800 |
| Zirconium | ** | ** |

TABLE 6
 Carbonaire Co., Inc.
 Palmerton, Pennsylvania
 HETA 91-073

Bulk Samples
 February 26, 1991

| Elements in terms of percent composition | | |
|--|--|---|
| | Dust from furnace filter of office trailer | Soil sample collected at southwest edge of property |
| Aluminum | 0.67 | 1.3 |
| Arsenic | 0.014 | ** |
| Barium | 0.047 | 0.072 |
| Beryllium | ** | ** |
| Calcium | 3.8 | 8.9 |
| Cadmium | 0.15 | 0.0084 |
| Cobalt | 0.0008 | 0.0027 |
| Chromium | 0.030 | 0.15 |
| Copper | 0.18 | 0.23 |
| Iron | 4.8 | 23.0 |
| Lithium | ** | ** |
| Magnesium | 0.64 | 2.0 |
| Manganese | 0.61 | 3.1 |
| Molybdenum | 0.013 | 0.025 |
| Nickel | 0.048 | 0.029 |
| Lead | 4.50 | 0.25 |
| Phosphorous | 0.12 | 0.045 |
| Platinum | ** | ** |
| Selenium | ** | ** |
| Silver | 0.0088 | 0.0044 |
| Sodium | 0.64 | 0.30 |
| Tin | 0.027 | 0.013 |
| Tellurium | ** | ** |
| Thallium | ** | ** |
| Titanium | 0.020 | 0.074 |
| Tungsten | 0.016 | ** |
| Vanadium | 0.004 | 0.011 |
| Ytterium | 0.0006 | 0.0008 |
| Zinc | 18.0 | 2.8 |
| Zirconium | ** | ** |

** Signifies that the amount of this element was below the analytical limit of detection.

TABLE 7
 Carbonaire Co., Inc.
 Palmerton, Pennsylvania
 HETA 91-073

Bulk Samples
 June 4, 1991

| Elements in terms of percent composition | | | | |
|--|--|---------------------------------|-------------------------------------|--|
| | Furnace filter dust from trailer | Dust from compressor area | Soil from NW area of property | Soil from CO ₂ loading area |
| Aluminum | 0.79 | 0.72 | 1.3 | 1.8 |
| Arsenic | 0.017 | 0.0086 | 0.015 | 0.021 |
| Barium | 0.014 | 0.017 | 0.082 | 0.057 |
| Beryllium | ** | ** | ** | ** |
| Calcium | 3.5 | 4.9 | 11.0 | 6.0 |
| Cadmium | 0.14 | 0.12 | 0.032 | 0.15 |
| Cobalt | 0.0011 | 0.0014 | 0.0013 | 0.0013 |
| Chromium | 0.033 | 0.087 | 0.046 | 0.015 |
| Copper | 0.19 | 0.24 | 0.052 | 0.10 |
| Iron 5.4 | 10 | 12 | 5.3 | |
| Lithium | 0.0013 | 0.0019 | 0.0021 | 0.0016 |
| Magnesium | 0.67 | 0.99 | 1.8 | 1.5 |
| Manganese | 0.62 | 1.4 | 5.9 | 2.5 |
| Molybdenum | 0.017 | 0.15 | 0.0040 | 0.0077 |
| Nickel | 0.024 | 0.32 | 0.011 | 0.0098 |
| Lead | 1.7 | 2.6 | 0.28 | 0.79 |
| Phosphorous | 0.089 | ** | ** | ** |
| Platinum | ** | ** | ** | ** |
| Selenium | 0.0070 | 0.010 | ** | |
| Silver | 0.0082 | 0.038 | 0.0016 | |
| Sodium | 1.0 | 0.74 | 0.14 | 0.31 |
| Tin | 0.017 | 0.0090 | ** | ** |
| Tellurium | ** | ** | ** | |
| Thallium | ** | ** | ** | |
| Titanium | 0.030 | 0.014 | 0.054 | 0.058 |
| Tungsten | 0.057 | 0.14 | 0.011 | 0.10 |
| Vanadium | 0.0045 | 0.0051 | 0.0046 | 0.0023 |
| Ytterium | ** | ** | ** | ** |
| Zinc | 18.0 | 16.0 | 4.0 | 14.0 |
| Zirconium | ** | ** | ** | ** |

** Signifies that the amount of this element was below the analytical limit of detection.

TABLE 7 (continued)
 Carbonaire Co., Inc.
 Palmerton, Pennsylvania
 HETA 91-073

Bulk Samples
 June 4, 1991

Elements in terms of percent composition

| | Soil from outside control room | Soil from floor of trailer |
|-------------|--------------------------------------|----------------------------------|
| Aluminum | 0.32 | 1.0 |
| Arsenic | ** | 0.11 |
| Barium | 0.013 | 0.31 |
| Beryllium | ** | ** |
| Calcium | 18.0 | 10.0 |
| Cadmium | 0.022 | 0.039 |
| Cobalt | ** | 0.0021 |
| Chromium | 0.11 | 0.062 |
| Copper | 0.52 | 0.16 |
| Iron | 3.2 | 18.0 |
| Lithium | 0.0009 | 0.0026 |
| Magnesium | 4.9 | 2.4 |
| Manganese | 0.58 | 3.1 |
| Molybdenum | ** | 0.017 |
| Nickel | 0.013 | 0.094 |
| Lead | 0.39 | 0.26 |
| Phosphorous | ** | 0.033 |
| Platinum | ** | ** |
| Selenium | ** | 0.013 |
| Silver | ** | 0.0029 |
| Sodium | 0.043 | 0.23 |
| Tin | ** | ** |
| Tellurium | ** | ** |
| Thallium | ** | ** |
| Titanium | 0.012 | 0.063 |
| Tungsten | 0.011 | 0.057 |
| Vanadium | 0.0058 | 0.0045 |
| Ytterium | ** | ** |
| Zinc | 3.4 | 3.0 |
| Zirconium | ** | ** |

TABLE 8
 Carbonaire Co., Inc.
 Palmerton, Pennsylvania
 HETA 91-073

Ammonia Concentrations
 June 4, 1991

| Job Title | Location | Sample Period | Ammonia Concentration (ppm) |
|----------------|----------------------|---------------|-----------------------------|
| Operator | Control room | 0650-1422 | |
| Supervisor | All locations | 0653-1455 | 4.7 |
| Compressor man | Gas compressors | 1327-1440 | |
| Ammonia Loader | Ammonia loading area | 0826-0904 | |
| Ammonia Loader | Ammonia loading area | 0904-0910 | |
| Compressor man | East compressor area | 1155-1200 | 122.6 |
| Area Sample | East compressor area | 0653-1455 | 113.1 |

TABLE 9
Carbonaire Co., Inc.
Palmerton, Pennsylvania
HETA 91-073

Ammonia Concentrations
February 26, 1991

| Location | Time (24 hour) | Concentration (ppm) |
|-------------------------------------|-------------------|------------------------|
| Between ammonia storage spheres | 0918 | 150 |
| West compressor area | 0924 | 7 |
| 25 feet southeast of compressors | 0925 | ND |
| Inside control room | 1212 | 4 |
| Between ammonia storage spheres | 1220 | 95 |
| East compressor area | 1305 | 30 |
| 20 feet south of compressors | 1300 | 5 |
| Between ammonia storage spheres | 1446 | 300 |

TABLE 10
Carbonaire Co., Inc.
Palmerston, Pennsylvania
HETA 91-073

Ammonia Concentrations
February 26, 1991

| Location | Time (24 hour) | Concentration (ppm) |
|------------------------------------|-------------------|------------------------|
| East compressor area | 0755 | 30 |
| East compressor area | 0758 | 250 |
| East compressor area | 0759 | 100 |
| Between two central compressors | 0802 | 7 |
| Between Ammonia Spheres | 1245 | ND |
| Between two central compressors | 1333 | 35 |