HEALTH HAZARD EVALUATION REPORT

HETA 90-0214-2523
RALSTON PURINA COMPANY
EVEREADY BATTERY COMPANY
MARIETTA, OHIO

PREFACE

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

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

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EVEREADY BATTERY COMPANY
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SUMMARY

On March 27, 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Oil, Chemical & Atomic Workers (OCAW) International Union to conduct a health hazard evaluation at the Ralston Purina Company Eveready Battery Company electrolytic manganese dioxide (EMD) plant in Marietta, Ohio. The union reported that two employees had Parkinson-like disease—a neurologic syndrome which could be related to chronic manganese toxicity.

The objective of this evaluation was to determine whether the neurologic abnormalities reported in the workforce could be related to work at the EMD plant. For the exposure assessment, NIOSH investigators reviewed and analyzed company records and conducted air sampling for manganese dust. The 29 full-shift evaluations for total manganese showed 8-hour time-weighted average (TWA) personal breathing zone (PBZ) concentrations ranging from 0.05 to 0.40 milligram per cubic meter (mg/m^3). The geometric mean of the TWA concentrations calculated over the actual sampling time was 0.16 mg/m^3 (standard deviation 1.8). All of these results were below the NIOSH recommended exposure limit (REL) of 1 mg/m^3 and the current American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) of 5 mg/m^3. However, 9 (31%) of these 29 measurements exceeded the proposed ACGIH TLV of 0.2 mg/m^3. None of the 15-minute PBZ samples for total manganese exceeded the NIOSH short-term exposure limit (STEL) of 3 mg/m^3 or the Occupational Safety and Health Administration (OSHA) ceiling limit of 5 mg/m^3. The six full-shift TWA PBZ concentrations of respirable manganese collected on production and maintenance workers ranged from 0.01 to 0.04 mg/m^3.

For the assessment of health outcomes, NIOSH investigators conducted a cross-sectional medical survey to determine whether current or former employees had clinically detectable neurologic abnormalities consistent with chronic manganese toxicity. Symptoms of tiredness, muscle aches, and cramps, and the physical finding of tremor were found more frequently among production and support workers than among nonproduction employees, but these differences were not statistically significant. Symptom indices for concentration, memory, anxiety, depression, motor function, and tremor were not statistically associated with work at the EMD plant. Work in the ferromanganese furnace departments outside the EMD plant was associated with symptom indices for concentration, memory, and motor function. However, workers in the furnace departments might have had exposures to potential neurotoxins (such as organic solvents) besides manganese.

This investigation did not show a statistical association between work in the EMD plant and adverse health outcomes among the workers as a group. However, the possibility that an individual worker's health was affected by work exposures could not be ruled out. Although the NIOSH air sampling results showed manganese exposures to be below the current NIOSH, OSHA, and ACGIH exposure criteria, some of the conditions and practices observed during the NIOSH site visits indicated a potential for occasional higher exposures. Therefore, recommendations to reduce employee exposures are provided in the recommendations section of this report.

KEYWORDS: SIC 3313 (Electrometallurgical Products, Except Steel), SIC 3691 (storage battery manufacturing), electrolytic nonferrous metal refining, manganese (Mn, CAS No. 7439-96-5), manganese dioxide (MnO_2, CAS No. 1313-13-9), neurologic movement disorder, manganism (ICD-9-CM 985.2), chronic manganese toxicity (ICD-9-CM 985.2), Parkinson-like disorder (ICD-9-CM 333.90), tremor (ICD-9-CM 781.0).

INTRODUCTION

On March 27, 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Oil, Chemical & Atomic Workers (OCAW) International Union to conduct a health hazard evaluation at the Ralston Purina Company Eveready Battery Company electrolytic manganese dioxide (EMD) plant in Marietta, Ohio. The union reported that two employees had Parkinson-like disease*—a neurologic syndrome which could be related to chronic manganese toxicity.

During the initial site visit on August 29 and 30, 1990, NIOSH investigators conducted air sampling and collected bulk specimens for elemental analysis. In addition, NIOSH investigators conducted confidential interviews and screening neurologic examinations of nine current employees selected by job title and seniority. On March 18, 1991, 79 current and former employees were surveyed to determine whether they had symptoms or neurologic findings consistent with chronic manganese toxicity. Additional industrial hygiene evaluations, including personal breathing zone (PBZ) samples for total and respirable manganese, were conducted on July 23 and 24, 1991.

BACKGROUND

Unprocessed manganese ore contains low-purity manganese dioxide contaminated primarily by common clay. At the Eveready EMD plant, manganese ore is electrolytically purified to produce high-grade manganese dioxide (MnO_2) powder. Manganese ore is black and the final product is a black powder. In the ore shed of the plant, finely pulverized manganese ore is unloaded by gravity and vibration through the bottom of railroad ore cars into a screw auger trench and pneumatically conveyed into storage silos. At the beginning of the purification process, the ore is transferred to a natural gas calciner (reduction furnace), where it is roast-heated at a high temperature to produce manganese oxide (MnO), an acid-soluble intermediate. The "roasted" ore is transferred to the leach area into tanks that contain sulfuric acid to produce a manganese sulfate ($MnSO_4$) solution. The solution is chemically treated to remove soluble impurities, then filtered to remove insoluble impurities. These processes remove iron, molybdenum, and other impurities from the ore.

The purified manganese sulfate solution is pumped into electrolytic cell tanks located in a large cell room. Each cell contains cathodes and anodes (metal plates). Manganese dioxide is deposited onto the anodes when electric current passes through the solution. After sufficient deposits form on the anodes, an overhead crane and hoist lift the plates from the cell and move them to the end of the cell room where the solidified manganese dioxide is stripped from the plates.

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*For definition of medical terms, see Glossary of medical terms after the Recommendations section.

Chunks of purified manganese dioxide are stockpiled in a covered area of the yard and transferred to the finishing building by a front-end loader and belt conveyers. In the finishing area, manganese dioxide is neutralized, dried, and milled into the final product (EMD), then bagged for shipment. Most of the EMD is packaged in 3,000-pound "supersacks" and transported off-site for use in the manufacture of dry-cell batteries. In the past, all of the EMD was packaged in 100-pound bags. Now, only a very limited amount of the final product is packaged this way.

Most of the production and maintenance employees work during the day shift on weekdays. Continuous leaching and plating operations require some employees to work other shifts. The job titles and primary responsibilities of production and maintenance workers are listed in Table 1. In addition to their primary responsibilities, maintenance workers' job descriptions include the performance of any of the production job titles as required by operating conditions and supervision. Maintenance workers, as well as production workers, may be required to operate mobile equipment to unload materials and product and to pile, store, and load the finished product.

Potential sources of employee exposure to manganese included unloading ore from railroad cars, collecting calciner samples for analysis, stripping purified manganese dioxide from the plates, transferring manganese dioxide to the finishing area, and milling and bagging the final product. Manganese-contaminated dust in the general work environment also could have contributed to exposure, especially during dry sweeping, eating or drinking dust-contaminated food, and smoking or chewing dust-contaminated tobacco.

Operations at the Eveready EMD plant in Marietta, Ohio, began in 1967 as a department of Union Carbide Corporation Metals Division. Other Metals Division departments of the Marietta operations included three ferromanganese-alloy furnace departments. In 1981, Union Carbide sold most of its Marietta metals plants, but continued to operate the EMD plant. In 1986, Ralston Purina Company acquired Eveready, including the Marietta EMD plant. In April 1987, a fire in the cell room closed the plant. During the plant closing, some process changes were made, and equipment and environmental controls were upgraded. Production resumed in July 1988. At that time, the company instituted a prohibition of smoking and eating in the production building. At the time of the initial NIOSH site visit, engineering measures included the ventilation system in the cell-room (with 4 supply-air fans and 11 roof exhaust fans); a dedicated dust collection system at the stripping operation; and exhaust ventilation systems in the finishing area.

Under Union Carbide, some employees voluntarily transferred between the EMD department and the ferromanganese-alloy furnace departments, where they had potential for exposure to manganese dust and fume. In addition, workers in one maintenance department had regularly scheduled six-month rotations between the EMD department and the ferromanganese-alloy furnace departments. When Union Carbide sold its furnace departments, some employees, especially those close to retirement, chose to remain with Union Carbide and transferred to the EMD department. Under Ralston Purina, hourly production workers were temporarily laid off during the plant closure after the 1987 fire. Not all recalled employees returned to work when the plant reopened in 1988.

EVALUATION CRITERIA

To assess the hazards posed by workplace exposures, NIOSH investigators use a variety of environmental evaluation criteria. These criteria are exposure limits to which most workers may be exposed for a working lifetime without experiencing adverse health effects. However, because of the wide variation in individual susceptibility, some workers may experience occupational illness even if exposures are maintained below these limits. The evaluation criteria do not take into account individual sensitivity, preexisting medical conditions, medicines taken by the worker, possible interactions with other workplace agents, or environmental conditions.

The primary sources of evaluation criteria for the workplace are NIOSH criteria documents and recommended exposure limits (RELs) [NIOSH, 1994], the Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs) [29 CFR 1910 (1989)]* and the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs) [ACGIH, 1994]. These occupational health criteria are based on the available scientific information provided by industrial experience, animal or human experiments, or epidemiologic studies. It should be noted that RELs and TLVs are guidelines, whereas PELs are legally enforceable standards. The NIOSH RELs are primarily based upon the prevention of occupational disease without assessing the economic feasibility of the affected industries and, as such, tend to be conservative. The OSHA PELs are required to take into account the technical and economical feasibility of controlling exposures in various industries where the agents are present. A Court of Appeals decision vacated the OSHA 1989 Air Contaminants Standard in *AFL-CIO v OSHA,* 965F.2d 962 (11th cir., 1992); and OSHA is now enforcing the previous standards (listed as Transitional Limits in 29 CFR 1910.1000, Table Z-1-A), which were originally promulgated in 1971. However, some states with OSHA-approved state plans continue to enforce the more protective ("final rule") limits promulgated in 1989. For exposures with evaluation criteria, NIOSH encourages employers to use the 1989 OSHA PEL or the NIOSH REL, whichever is lower.

Evaluation criteria for chemical substances are usually based on the average PBZ exposure to the airborne substance over an entire 8- to 10-hour workday, expressed as a time-weighted average (TWA). Personal exposures are usually expressed in parts per million (ppm), milligrams per cubic meter (mg/m^3), or micrograms per cubic meter (µg/m^3). To supplement the TWA where adverse effects from short-term exposures are recognized, some substances have a short-term exposure limit (STEL) for 15-minute periods; or a ceiling limit, which is not to be exceeded at any time. Additionally, some chemicals have a "skin" notation to indicate that the substance may

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**Code of Federal Regulations.* See CFR in references.

be appreciably absorbed through direct contact of the material or its vapor with the skin and mucous membranes.

It is important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these occupational health exposure criteria. A small percentage may experience adverse health effects because of individual susceptibility, preexisting medical conditions, previous exposures, or hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, or with medications or personal habits of the worker (such as smoking) to produce health effects even if the occupational exposures are controlled to the limit set by the evaluation criterion. These combined effects are often not considered by the chemical-specific evaluation criteria. Furthermore, many substances are appreciably absorbed by direct contact with the skin and thus potentially increase the overall exposure and biologic response beyond that expected from inhalation alone. Finally, evaluation criteria may change over time as new information on the toxic effects of an agent become available. Because of these reasons, it is prudent for an employer to maintain worker exposures well below established occupational health criteria.

Manganese

Manganese is an abundant element present throughout the environment and can be found in soil, water, air, and vegetation [WHO, 1981]. Manganese is very reactive and, therefore, elemental manganese does not occur naturally. Manganese exists in numerous oxidation states and is a major component of over 100 minerals. Pyrolusite, a black mineral containing approximately 60% manganese dioxide, is one of the most common and commercially important forms of manganese [ACGIH, 1992]. The importance of manganese in manufacturing includes its uses in steel and metal alloys (to improve strength and hardness), in ceramic and glass products, in rubber and wood preservatives, and in dry-cell batteries.

Manganese is also important for human physiology. It is an essential trace element necessary for such functions as the formation of connective tissue and bone and the metabolism of carbohydrates (sugars and starches) and lipids (fats) [WHO, 1981]. For these reasons, adult humans require two to three milligrams (mg) of dietary manganese per day [WHO, 1981].

Occupational overexposures to manganese can result in Parkinson-like neurologic effects, pneumonitis, psychosis, and metal fume fever. Symptoms of the early neurologic effects of manganese toxicity, such as apathy (asthenia, malaise), loss of appetite (anorexia), sleepiness (somnolence), and nervousness may be related to a number of other causes. Advanced disease, however, is characterized by findings such as slow or minimal movement (brady- or hypokinesia); difficulty standing (postural instability); difficulty walking (gait disturbance), particularly when turning, or difficulty stopping when walking forward (propulsion) or backward (retropulsion); a smooth and expressionless face (mask-like facies); monotonous voice; slow or irregular speech (such as stuttering); clumsy alternating movements (dysdiadochokinesia); increased muscle tone (rigidity, dystonia); tremor; and increasingly small writing (micrographia) [Rodier, 1955; Cook et al., 1974]. The condition may develop insidiously after months or years of manganese exposure [Rodier, 1955]. Although the condition may be reversible after early removal from exposure, it is often unrecognized until the worker is severely and irreversibly affected [Rodier, 1955]. This condition has been called manganese poisoning, manganism, and chronic manganese toxicity.

The primary route of occupational exposure to manganese is inhalation of dust or fume. For absorption through the lungs, manganese dust and fume must be of respirable size to reach the air sacs (alveoli). However, most inhaled manganese is carried out of the lungs by the mucociliary action of the airway walls, then swallowed [Mena et al., 1969]. Inhaled manganese thus becomes available for gastrointestinal absorption. An experimental study of adult humans showed that three percent of manganese ingested (eaten) by healthy subjects is absorbed, three to five percent by subjects with chronic manganese toxicity, and up to ten percent by unexposed anemic subjects [Mena et al., 1969].

In a dry-cell battery plant, 8 (22%) of 36 workers showed neuropsychiatric evidence of manganese toxicity [Emara et al., 1971]. Two of these workers showed chronic movement abnormalities. Air concentrations of manganese dust at this plant averaged 33 to 42 mg/m^3 in the unpacking, sieving, and mixing areas, and 7 mg/m^3 in the compressing area. Air concentrations at this dry-cell battery plant were higher than current NIOSH, OSHA, and ACGIH evaluation criteria. In a survey of industries using manganese, 7 (6%) of 117 workers in plants with exposures of 5 mg/m^3 or greater had clinical signs of manganese toxicity [Tanaka et al., 1969]. None of the 48 workers screened in plants with exposures less than 5 mg/m^3 had signs of manganese toxicity [Tanaka et al., 1969].

More recent studies show that workers exposed to air concentrations close to or below the NIOSH, OSHA, and ACGIH evaluation criteria have more preclinical findings (mild abnormalities that would not typically be looked for or recognized as medical problems) than workers who are not exposed to manganese [Roels et al., 1987b; Wennberg et al., 1991; Roels et al., 1992]. At a manganese oxide- and salt-producing plant where air concentrations of manganese averaged 1.33 mg/m^3 (arithmetic) and 0.94 mg/m^3 (geometric), exposed workers had statistically significant higher prevalences of abnormal psychomotor test results for simple reaction time, short-term memory, and hand tremor than unexposed workers [Roels et al., 1987a; Roels et al., 1987b]. At two steel smelting works where air concentrations of manganese ranged from 0.19 to 1.39 mg/mg^3, psychomotor test results for simple reaction time, short-term memory (digit span), and recent mood were weakly correlated with respirable dust exposures [Wennberg et al., 1991]. Studies at the manganese oxide- and salt-producing plant and the steel-smelting works also suggested the possibility of decreased fertility and decreased libido among exposed workers [Lauwerys et al., 1985; Wennberg et al, 1991]. Workers at a dry-cell battery plant had higher prevalences of abnormal psychomotor test results for simple reaction time and hand-eye coordination than unexposed workers [Roels et al., 1992]. Although the average air concentrations of total manganese (1.78 mg/m^3 arithmetic; 0.95 mg/m^3 geometric) at the battery plant were similar to those at the manganese oxide- and salt-producing plant, battery plant workers had lower prevalences of psychomotor test abnormalities than workers at the oxide- and salt-producing plant [Roels et al., 1992]. The lower lifetime integrated exposures of battery plant workers and the lower biological availability of manganese dioxide (compared with other manganese oxides and salts) could explain this difference [Roels et al., 1992]. At the battery plant, the average air concentration of respirable manganese was 0.30 mg/m^3 (arithmetic; 0.22 mg/m^3 geometric) [Roels et al., 1992].

Because chronic manganese toxicity is insidious in onset and potentially irreversible, workplace exposures must be controlled to prevent disease (primary prevention). The NIOSH REL for total manganese dust is an 8-hour TWA of 1.0 mg/m^3, with a STEL of 3.0 mg/m^3. These limits were set to prevent clinical effects such as chronic manganese toxicity and pneumonitis [CDC, 1988; NIOSH, 1992]. The OSHA PEL for total manganese dust is a ceiling limit of 5.0 mg/m^3 [29 CFR 1910.1000]. The current ACGIH TLV is an 8-hour TWA of 5 mg/m^3 for manganese dust. The ACGIH TLV for manganese fume (1 mg/m^3) is lower than the TLV for manganese dust because the fume is more potent than the dust in causing chronic manganese toxicity [Smyth et al., 1973; ACGIH 1994]. However, ACGIH has published a notice of intended change that would lower the TLV for elemental and inorganic manganese dust and fume to 0.2 mg/m^3 [ACGIH, 1995b]. This change was recommended to reduce respiratory symptoms (such as cough during cold seasons, shortness of breath during exercise, acute bronchitis), preclinical psychomotor abnormalities, and decreased fertility (of male workers) that have been associated with exposures within the current TLVs [Lauwerys et al., 1985; Roels et al., 1987b; ACGIH, 1995b].

INDUSTRIAL HYGIENE SURVEYS

Methods

NIOSH Survey

On August 30, 1990, and July 23 and 24, 1991, NIOSH investigators conducted air sampling for manganese dust throughout the EMD plant. Twenty-nine full-shift and six short-term personal breathing zone (PBZ) evaluations for total manganese were collected on production workers (relief operators, chemical operators, cell monitors, cell processors, product processors) and support personnel (mechanics and a supervisor). In addition, 36 area air samples were collected throughout these employees' work areas (ore shed, leach area, cell room, and finishing area). These included 17 pairs of side-by-side samples to determine the respirable component of total manganese. To characterize the particle sizes of airborne manganese and all dusts, paired samples for manganese and gravimetric analyses were collected above a chemical leach tank in the leach area, inside the noise barrier for the plate stripper in the cell room, and on the core-sample table in the finishing area.

The PBZ and area samples for total manganese were collected on 0.8-micron (μ) pore size, mixed cellulose ester (MCE) filters at a flow rate ranging between 2 and 2.5 liters per minute (lpm). Samples for respirable manganese were collected on MCE filters in 10-millimeter nylon Dorr-Oliver cyclones with particle size selecting devices at a flow rate of 1.7 lpm. Samples for characterizing particle size were collected with tared polyvinyl chloride (PVC) filters.

All samples were analyzed by NIOSH method 7300 for elemental manganese by inductively coupled argon plasma, atomic emission spectroscopy (ICP-AES) after an acid digestion procedure using nitric and perchloric acids. The analytic results may slightly underestimate the actual quantity of manganese present in the sample because the acid digestion procedure may not fully dissolve particulate manganese dioxide. The three pairs of side-by-side samples collected for particle size were also analyzed gravimetrically.

For full-shift PBZ exposures to total manganese, arithmetic means and standard deviations were calculated by sampling year, job title, work area, and also by the exposure categories used in the statistical analyses of the NIOSH medical survey of this report. Because worker exposures to particulate air contaminants generally have a log-normal distribution [Cooper, 1993], geometric means and standard deviations were also calculated. For the side-by-side area air samples, the percentage of respirable manganese in total airborne manganese was calculated. Results of the paired samples analyzed gravimetrically for total (composition) weight were also used to calculate the percentage of manganese in total dust (all particle sizes), the percentage of manganese in respirable dust, and the percentage of respirable dust in total dust.

Company's evaluations

NIOSH investigators obtained and analyzed records of the company's industrial hygiene sampling for worker exposures to total and respirable PBZ manganese. The data included exposure measurements made from 1977 to 1990 for TWA and short-term exposures to total manganese and TWA exposures to respirable manganese. (Often, the company used half-shift TWAs as surrogates for 8-hour TWA exposures.) For each of the different types of data, arithmetic and geometric means were calculated. The results were tabulated to summarize exposures for all years combined, pre- versus post-fire years, each year (annual) for all work areas combined, each year for the finishing area, each job title, each work area, and each exposure category used in the statistical analyses of the NIOSH medical survey of this report.

Results

NIOSH survey

Table 2 shows the results of full-shift PBZ monitoring conducted for total manganese on six production workers, a mechanic, and a supervisor during the initial NIOSH survey on

August 30, 1990. Tables 3 and 4 show the results of full-shift PBZ monitoring conducted for total manganese on 11 production workers and 10 mechanics, respectively, during the follow-up survey on July 23 and 24, 1991. The 8-hour TWA concentrations of these 29 measurements ranged from 0.05 to 0.40 mg/m^3 (Tables 2, 3, and 4). Table 5 summarizes the full-shift PBZ exposures by year, job title, and work area, and also by the exposure categories used in the statistical analyses of the NIOSH medical survey of this report. No differences in exposure were found between the two site visits. Because all five relief operators and one mechanic performed tasks of other job titles, their exposures were summarized according to the job tasks they performed during the air sampling as well as their own job title. For example, the exposure of a relief operator working as a chemical operator was included as an exposure to a chemical operator as well as to a relief operator. The TWA (actual) concentrations observed during task-based monitoring ranged from 0.05 to 0.47 mg/m^3, with a geometric mean of 0.16 mg/m^3 (standard deviation [s.d.] 1.8). The highest concentration (0.47 mg/m^3) was measured on a relief operator assisting the product processor in the finishing area. Eleven full-shift PBZ measurements were collected on mechanics, primarily during scheduled preventive maintenance activities. Of these, the highest 8-hr TWA concentration (0.40 mg/m^3) was measured on the mechanic who worked in the leach area. The geometric means of exposures to production workers in the leach area, cell room, and finishing area were 0.11, 0.17, and 0.23 mg/m^3, respectively. All of the 29 full-shift TWA PBZ exposure measurements were below the 8-hour TWA NIOSH REL of 1 mg/m^3 and the current ACGIH TLV of 5 mg/m^3. However, 9 (31%) of these 29 measurements exceeded the proposed ACGIH TLV of 0.2 mg/m^3. Measurements exceeding the proposed TLV were found throughout the plant.

Table 6 shows the results of the six 15-minute PBZ exposure measurements for total manganese. The highest short-term exposure measured was 1.73 mg/m^3 on the relief operator while emptying and disposing manganese dioxide bags in the leach area. None of the short-term exposure measurements exceeded the NIOSH STEL of 3 mg/m^3 or the OSHA ceiling limit of 5 mg/m^3.

Table 7 shows the full-shift PBZ exposure to respirable manganese collected on a relief operator, metal processor, product processor, and three mechanics. Concentrations ranged from 0.01 to 0.04 mg/m^3, with the highest concentration measured on a metal processor in the cell room.

Tables 8 and 9 show the results of 35 area samples, including the 17 pairs of side-by-side samples for total and respirable manganese. The highest concentration of total manganese was measured in the finishing area near the bagging machine when a seal failed, requiring corrective maintenance. The calculated respirable fraction of total manganese averaged 13% with a range of 1.3 to 25% (Table 8). The highest respirable fraction was measured in the leach area and the lowest was in the cell room. The percent manganese (by weight) ranged from 27 to 38% in total dust and from 13 to 33% in respirable dust (Table 9).

Company's evaluations

The company's results of industrial hygiene sampling for manganese for the years 1977 through 1990 are summarized in Appendix Tables 1 through 8. The company's records showed a change in sampling strategy after the 1987 fire. Before the fire, all TWA evaluations were for exposures to total manganese. After the fire, all TWA evaluations were for exposures to respirable manganese. Half-shift measurements were often used as a surrogate for full-shift TWA evaluations. Short-term exposures to total manganese were measured during both periods.

Appendix Table 1 summarizes all results by type of exposure measurement. For each type of measurement, a few exposures ("outliers") appeared to be excessive when compared to the other results. These exposures occurred during the performance of unusual tasks (such as change of baghouse filters) and did not represent typical exposures during normal operations or routine tasks. Therefore, these outliers were not included in the summaries presented in the other tables of the appendix.

Appendix Table 1 shows that, before 1989, company measurements of manganese exposures were occasionally above the NIOSH REL, OSHA PEL, and ACGIH TLV. Samples taken by the company during an OSHA inspection on July 18, 1989, showed 15-minute concentrations of 6.94 mg/m^3 and 5.33 mg/m^3 at the bagger's (product processor) position. These concentrations are above the OSHA ceiling limit of 5 mg/m^3 and the NIOSH STEL of 3 mg/m^3. Furthermore, the geometric mean of all company data for TWA exposure to total manganese (0.56 mg/m^3) exceeds the proposed ACGIH TLV of 0.2 mg/m^3.

Appendix Tables 2, 3, and 4 summarize 128 TWA exposure measurements for total manganese by year for all jobs combined, by year for the finishing area, and by job title for all years combined, respectively. The annual geometric means for TWA exposures to total manganese were considerably higher before 1983 (range 1.29-2.92 mg/m^3) than after 1983 (range 0.18 -0.39 mg/m^3). The reduction in exposure after 1983 might have been related to improved engineering controls, administrative controls, and the inclusion of lower exposure jobs in the industrial hygiene monitoring program. For example, 41 (85%) of the 48 samples collected before 1983 were from the finishing area (where the final product is processed and packaged), in comparison to 47 (59%) of the 80 samples collected after 1983. In addition, the geometric mean TWA exposure for total manganese in the finishing area was much higher before 1983 (1.91 mg/m^3) than after 1983 (0.31 mg/m^3). Most of the exposure evaluations for total manganese were conducted on relief operators, process operators, and baggers in the finishing area. Although only three evaluations were conducted on workers unloading ore cars, these workers had the highest geometric mean TWA exposure (1.61 mg/m^3) for total manganese. Workers in the finishing area had the next highest geometric mean TWA exposures (baggers, 1.04 mg/m^3; process operators, 0.43 mg/m^3) as well as the highest individual exposures (baggers, 12.75 mg/m^3; process operators, 11.5 mg/m^3) to total manganese. Although mechanics and electricians had the lowest geometric mean TWA exposures to total manganese, the standard deviations (9.08 and 6.56, respectively) were extremely high because of the high variability of the measurements in the records.

Appendix Table 5 summarizes the TWA exposure measurements for respirable manganese by year and by job title. The highest geometric means were among workers unloading ore cars (0.17 mg/m^3) and workers processing and packaging the final product in the finishing area (0.1 mg/m^3). The results show the same rank order of relative exposure by job title as did the total manganese results.

Appendix Table 6 summarizes the short-term monitoring results for total manganese. Short-term monitoring was conducted for only four years, but two years (1982 and 1983) were before the fire and two (1989 and 1990) were after the fire. Short-term exposures in 1980 and 1982 did not appear to differ from exposures in 1989 and 1990. Only three job tasks were sampled—ore shed unloading, bagging, and product processing. Although some individual results were above the OSHA ceiling limit (5 mg/m^3) and the NIOSH STEL (3 mg/m^3), all of the geometric means for short-term exposure to total manganese by job task and job title were below the NIOSH STEL. However, observed short-term exposures are highly dependent on the tasks selected for evaluation, and the exact nature of each task performed during STEL measurements was not apparent in most of the company's records. Therefore, the geometric means cannot be used to validly estimate typical exposures.

Appendix Table 7 summarizes workers' manganese exposures by sample type (short-term total, TWA total, TWA respirable) and work area. The highest individual manganese exposures (12.75 mg/m^3 for total, 0.62 mg/m^3 for respirable) and the highest geometric means (0.72 mg/m^3 for total, 0.1 mg/m^3 for respirable) were measured in the finishing area. Although maintenance workers had a lower geometric mean exposure to total manganese (0.15 mg/m^3) than workers in the leach area (0.33 mg/m^3) and cell room (0.25 mg/m^3), one maintenance worker had a TWA exposure (8.24 mg/m^3) that exceeded the highest exposures in those other areas. This suggests that maintenance workers could have occasional higher exposures even though their daily exposures are typically lower than those of production workers.

Appendix Table 8 summarizes workers' manganese exposures by the exposure categories used in the statistical analysis of the NIOSH medical survey of this report. Although exposures within both groups were highly variable with some overlap, the geometric mean for TWA exposure to total manganese was higher for production workers (0.57 mg/m^3) than for support workers (0.15 mg/m^3). The high geometric standard deviation for the support workers is probably related to the small number (9) of measurements as well as the high variability of the results.

INITIAL MEDICAL SURVEY

Methods

On August 30, 1990, the NIOSH medical officer conducted confidential interviews and limited medical examinations of nine (50%) high seniority day-shift production employees selected from different job titles. The interviews focused on environmental conditions at the plant and on symptoms among workers. The screening examinations were performed to detect signs of manganese toxicity, such as tremor, abnormal gait, and rigidity. The Occupational Safety and Health Administration (OSHA) Form 200 (Log and Summary of Occupational Injuries and Illnesses) and workers compensation claims for the years 1985 to 1990 were reviewed for reports of neurologic illnesses.

Results

The interviewed employees reported that production workers (product processors, relief operators, cell processors, and chemical operators) had the highest potential for exposure to manganese dust. Among production workers, product processors were reported to have the highest potential for exposure. Maintenance workers, engineers, and supervisors were reported to have a lower potential for exposure than production workers, but could have intermittent heavier exposures during assessment and repair of equipment breakdowns that result in spills or leaks. The interviewed employees reported that, in the past, the highest potential for exposure to manganese dust occurred in the ore shed during unloading, in the cell room while stripping manganese dioxide from the plates and sweeping the floor, and in the finishing area from chute, blender, and batch-dryer leaks and during bagging operations. Use of 100 pound bags (no longer regularly used) and lining of uncleaned, reused bags were reported to be especially dusty. The interviewed employees reported that, on some days in the past, the airborne dust was so bad they had trouble recognizing nearby co-workers. They also reported that, in the past, the floor of the finishing area was often thickly covered with dust. They stated that special clean-up operations were performed shortly before environmental sampling or the arrival of visitors. They stated that a truck with an industrial vacuum unit (which they referred to as "super sucker") was brought in to clean the plant shortly before the NIOSH site visit. However, most employees volunteered that environmental conditions at the plant had greatly improved since the post-fire renovations of 1987 and 1988.

During the walk-through survey of the initial site visit, NIOSH investigators observed accumulations of manganese ore on the ground of the ore shed and fine, black dust on the floor and ground in the finishing area and near the stripping area of the cell room, where an employee was seen dry sweeping.

Eveready management confirmed that the industrial vacuum unit was at the plant on August 17, 1990, but stated that its use was unrelated to the NIOSH site visit on August 30. They stated that the vacuum unit is used for special jobs such as clearing drains and cleaning spills in addition to removing environmental dust. They disagreed with the employees' descriptions of workplace exposures, which they stated had not been substantiated by environmental sampling data.

The interviewed employees reported that "dust masks" were used during bagging of the 3,000-pound supersacks and occasionally during other extremely dusty tasks. Production employees wore and laundered their own work clothes. Maintenance workers personally paid for a laundry service, which provided a daily change of coveralls.

Eveready management reported that wet methods are used for environmental dust control. Specific dusty jobs are covered by the respiratory protection program that has been in effect, according to company records, since at least 1985. The revised program, instituted on January 1, 1989, requires use of proper respiratory protection when using the floor sweeper, working in the dust collectors, dumping filter aid, and lining supersacks. Disposable particulate respirators (3M 8710 and 3M 9920) were considered acceptable, but employees were also given the option to use portable, supplied-air respirators.

Eveready also has a hazard communication program which began in 1986. However, employees expressed concerns that they had not been adequately educated about the health effects of exposure to manganese dust.

Before the plant closed in 1987, smoking was permitted in the building. When the plant reopened in 1988, Eveready instituted a policy prohibiting smoking within the building. However, at the time of the initial site visit, smoking was still allowed in the outdoor unloading area, where NIOSH investigators observed cigarette butts in the ore dust on the ground.

On limited physical examination, several employees were found to have evidence of possible Parkinson-like findings (tremor, rigidity, mask-like facies). In addition, several former employees were reported by co-workers to have nervous system disorders. A review of company workers' compensation records revealed that two former employees claimed that their neurologic impairments were related to manganese dust exposure at the EMD plant.

MEDICAL SURVEY

Purpose

Eveready's environmental sampling records generally showed manganese exposures to be below the evaluation criteria, but a few measurements showed excessive exposure (Appendix Tables 1-8). However, if actual exposures were generally below the evaluation criteria, as suggested by the historic records, the finding of possible neurological impairment in several current and former employees raised the possibility that chronic manganese toxicity might occur even at those exposure levels. Therefore, a cross-sectional medical study was conducted to determine whether current or former employees, hourly or salaried, had clinically detectable neurologic impairment consistent with chronic manganese toxicity.

Methods

On March 18, 1991, NIOSH investigators conducted medical evaluations of current and former production and nonproduction employees to determine whether potentially exposed workers had developed Parkinson-like illnesses or other signs of chronic manganese toxicity. All current and former employees, except for summer hires and interns, were eligible to participate. One-hundred nineteen employees were identified through personnel records and invited to participate.

Medical evaluation

All participants were asked to complete a self-administered questionnaire addressing demographic information, neurobehavioral and neurologic symptoms, history of certain medical conditions, personal habits, and exposures to potential neurotoxins besides manganese. Participants rated how much each symptom bothered them on discrete five-point response scales (ranging from "not at all" to "extremely"). Two neurologists who specialize in Parkinson's disease performed screening examinations to assess gait, rapid alternating movements, hand oscillation, thumb-index finger position, cogwheel phenomenon, rigidity of the neck and trunk, balancing of arms, tremor of fingers during walking, drawing of a spiral ("Archimedes' circle"), handwriting ("Mary had a little lamb"), and facial expression. The neurologists assessed speech, facial expression, tremor at rest, action or postural tremor of hands, rigidity, finger taps, hand movements, rapid alternating movements of hands, foot agility, ability to rise from a chair, posture, gait, postural stability, and body bradykinesia and hypokinesia using the Unified Parkinson's Disease Rating Scale (UPDS) [Fahn et al., 1987] and the New York University Parkinson's Disease Scale (NYUPDS) [Lieberman, 1974]. They assessed severity of impairment with the Hoehn and Yahr staging [Hoehn et al., 1967], Schwab and England Activities of Daily Living Scale [Schwab et al., 1968], and the Northwestern University Disability Scale (NUDS) [Canter et al., 1961]. Each participant was notified in writing of the results of his or her individual examination.

Exposure assessment

Historic environmental sampling results and results of the NIOSH industrial hygiene surveys were reviewed to determine whether exposures within job titles, work area, and time periods (to reflect changes in processes and engineering controls, such as those made during renovations after the fire) could be quantitatively described. However, historical data was sparse, and Eveready used different sampling methods before (total dust) and after (respirable dust) the 1987 fire. In addition, the results of current sampling could not be used to estimate exposures before 1987 because of process and equipment changes. Therefore, job titles were used as a surrogate measure of exposure. Three exposure categories were used for the statistical analysis. Production workers were considered to have had the highest potential for exposure to manganese dust. Production workers included product processors, cell processors, relief operators, and chemical operators. Analyses of job-title changes within exposure categories showed that many production employees had worked at more than one production job. More importantly, workers in this category could be assigned to perform duties of production jobs other than their own (Table 1). Support personnel were considered to have had an intermediate potential for exposure to manganese dust. They generally had a low potential for exposure, but could have had intermittent heavier exposures during scheduled preventive maintenance and from spills and leaks during breakdowns. Support personnel included production managers, supervisors, engineers, and maintenance workers. Nonproduction personnel, such as office workers, laboratory workers, and management personnel, had duties that rarely or never took them into production areas. They were assigned to the category with the lowest potential for exposure. Each eligible employee's job history (job title, number of months in each job title, and date of last record) was abstracted from employee service records maintained at the plant. Job history information about employees who had retired before Union Carbide sold the EMD plant to Ralston Purina were not available from Eveready or Union Carbide. These retirees were asked to provide the missing information by mail. One retiree participant who did not respond to the written request could not be reached by telephone.

Statistical analyses

The following outcome variables were used in the analyses: symptoms of tiredness, sleeping more often than usual, and muscle aches; symptom indices of concentration, memory, anxiety, depression, motor function, and tremor; and physical finding of tremor (of the tongue and lips as well as the extremities). Other symptoms and examination abnormalities were reported or found in numbers too small for meaningful quantitative analysis. Responses for symptoms of tiredness, sleeping more than usual, and muscle aches were dichotomized ("not a problem" and "a little" *versus* "moderately," "quite a bit," and "extremely"). Symptom indices of concentration, memory, anxiety, depression, motor function, and tremor were created by combining questionnaire responses for symptoms that were related to each other. The variables included in an index were tested for internal consistency reliability using Cronbach's coefficient alpha, which estimates the correlation between the sum of scores from the selected variables and the sum of scores from a comparable series of variables. Table 10 shows the variables included in each symptom index. The scores of an index's variables were averaged, and each index was treated as continuous variable. The physical finding of any tremor was dichotomized (presence or absence).

Multivariable regression models were developed to identify predictors or risk factors (independent variables) for the outcome variables. Independent variables were screened to determine whether they should be entered in the models. The following variables were entered: work in the EMD plant, work in the ferromanganese furnace departments, work in the EMD plant before the 1987 fire, eating in the work area, using tobacco in the work area, age, and cumulative alcohol consumption. Work in the EMD plant was categorized first by the highest exposure job assignment (production, support, or non-production) a participant ever worked in, then by number of years in production (never, less than five, and five or more). Work in the EMD plant before the 1987 fire was a dichotomous variable (yes or no). Work in the ferromanganese furnace departments was a continuous variable (duration). Eating in the work area and using tobacco in the work area were used as either continuous (duration) or dichotomous (ever or never) variables. Because cumulative alcohol consumption was nonlinear in the logit, it was dichotomized (the equivalent of less than two drinks per day for 10 years *versus* the equivalent of two or more drinks per day for ten years).

Stepwise logistic regression methods were used for the dichotomized outcome variables (individual symptoms and physical finding of tremor) and analyses of covariance for the continuous variables (symptom indices). Work in the EMD plant and age were included in the final models regardless of their statistical significance. Other independent variables were included in the final model only if significant at a p-value of ≤ 0.05. Work-history variables were tested for statistical interactions with variables that could have increased an exposed worker's exposure to manganese— work in the EMD plant before the 1987 fire, eating in the work area, and using tobacco in the work area.

The odds ratio, which is calculated during the logistic regression analysis, is a measure of the risk of experiencing the outcome variable if the independent variable is present. An odds ratio greater than 1.0 indicates an association between the independent variable (such as exposure category) and the outcome variable (such as symptom or examination abnormality). The 95% confidence interval (CI) indicates the probable range within which the odds ratio actually falls. Ordinarily, if the CI includes 1.0, the association between the independent variable and outcome variable could have occurred by chance alone and the elevated odds ratio is not considered statistically significant.

Results

Of the 119 eligible employees, 79 (66%) participated in the study. The participants included 32 (94%) of 34 active hourly employees, 20 (87%) of 23 active salaried employees, 16 (55%) of 29 retirees, and 11 (33%) of 33 former employees who left for reasons other than retirement (such as those who chose not to return to the plant when it reopened after the 1987 fire). One participant's results were not included in the analyses because of missing job history information. Table 11 compares the number of years participants and nonparticipants worked in the three EMD plant exposure categories and in the ferromanganese furnace departments. Participants had longer histories of working in production job titles than did nonparticipants, but shorter histories of working in the ferromanganese furnace departments.

Table 12 shows participants' age, years of schooling, work histories, histories of exposure to potential neurotoxins, and alcohol consumption by job category. Cumulative alcohol consumption and age were not correlated ($r = -0.14$ for those who ever consumed alcohol).

Table 13 shows the mean scores* and numbers of positive questionnaire responses for symptom variables and mean scores for symptom indices by the highest exposure category an employee ever worked in. The highest mean scores for symptom variables were 2.4 for tiredness and for muscle aches or cramps in production workers. Production workers had higher prevalences of tiredness (40%) and muscle aches or cramps (38%) than workers in the other two categories. Nonproduction employees and production workers had higher prevalences (31% and 27%, respectively) of "sleeping more than usual" than support workers (6%). However, the mean scores for these symptom variables were not significantly different among the three exposure categories. After adjusting for other independent variables, work in the EMD plant was not associated with any of the symptoms.

For each symptom index, the mean scores for production and support workers were slightly higher than the mean score for nonproduction employees. The highest mean score for a symptom index was 2.3 for symptoms of depression among support workers. Work in the EMD plant was not associated with any of the symptom indices after adjusting for the other independent variables. In some of the models for symptom indices, one or more of the other independent variables were strongly associated ($p < 0.05$) with the outcome variable. Most of these variables (work in the EMD plant before the 1987 fire, eating in the work area, and using tobacco in the work area) had been entered into the model to test for statistical interaction with work in the EMD plant and work in the ferromanganese furnace departments. Table 14 shows the prevalences of these variables by exposure category. Except for the uncommon use of tobacco among nonproduction employees, the prevalences of positive responses across the exposure categories were similar. Work in the ferromanganese furnace departments significantly contributed to the symptom index models for concentration, memory, and motor function. A statistical interaction between work in the ferromanganese furnace departments and smoking cigarettes at work was found in the model for the symptom index of motor function when using number of years in production (never, less than five, and five or more) as the exposure variable.

Table 15 shows the prevalences of physical findings noted by the neurologists during the screening examinations. Thirty-two (41%) of all participants had at least one finding. Tremor, found in 28 (36%) of all participants, was the most common finding. The tremors involved the upper extremities, tongue, or lips. All but one of the tremors were mild (0.5 to 1 on a scale of 0 to 4, with 0 = "no tremor observed"). One participant's tremor was more pronounced, but not severe (value of 2 on a scale of 0 to 4). Other findings were observed in less than 10% of all participants, and included neck rigidity, bradykinesia, postural instability, impaired writing, gait disturbance, and impaired drawing of a spiral. Most of these findings were mild. The neurologic findings were more prevalent among production and support workers than among nonproduction employees. Twenty-two (69%) of the 32 participants with neurologic findings had worked in production or support job titles for five or more years, and 15 (47%) had worked in those job

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*A score is a subjective assessment of how much the symptom bothered the respondent in the month before the survey, with "2" indicating "a little" and "3" indicating "moderately."

titles for ten or more years. Of the 47 participants with no neurologic findings, 37 (58%) had worked in production or support jobs for five or more years, and 12 (26%) had worked in those jobs for ten or more years. However, about 50% of the 32 participants with neurologic findings gave a history of nonoccupational factors (such as age, medical condition, or alcohol consumption) that could have contributed to the finding. About 70% of these 32 participants also gave a history of exposure to potential neurotoxins (such as arsenic, cadmium, lead, mercury, carbon disulfide, solvents, and pesticides) besides manganese.

When using the highest exposure category ever worked in (production, support, nonproduction) as an independent variable and any tremor as the outcome variable, the odds ratio was higher for work in production (1.8, CI 0.4-4.9) than for work in the support category (1.3, CI 0.2-7.4). The odds ratio was lower for working more than five years in production (1.4, CI 0.5-4.5) than for working in production for five or fewer years (1.9, CI 0.5-6.8). In both of these models, the job exposure variables were less important than cumulative alcohol consumption (odds ratio 2.1, CI 0.6-7.3) dichotomized at the equivalent of two drinks per day for ten years. Other variables that remained in the model were age (odds ratio 1.0) and years worked in the furnace department (odds ratio 1.0). Work in the EMD plant before the 1987 fire, eating in the work area, and using tobacco in the work area did not meet the criteria for remaining in these models.

DISCUSSION

Eveready's historical environmental sampling results for manganese were generally below the current evaluation criteria. However, results before 1987 documented occasional excessive exposures for some employees (Appendix Tables 2, 3, and 5). Although the sparse sampling data are not representative of all exposures over time, two observations were made. First, overall exposures appeared to decrease after 1983. Second, differences in exposures related to type of work (such as production versus maintenance) appeared to decrease after 1987. The second observation may be related to renovations in the finishing area after the 1987 fire.

Although some symptoms (such as tiredness, muscle aches and cramps), symptom indices (such as concentration and memory), and a physical examination finding (tremor) were found more frequently among production and support workers than among nonproduction employees, these differences were not statistically significant. After adjusting for other independent variables, none of these outcome variables were found to be associated with work in the EMD plant (by highest exposure category ever worked in or by category of years worked in production). For the physical finding of tremor, cumulative alcohol consumption (dichotomized at the equivalent of two drinks per day for ten years) was more important than the work-exposure variable. Tremors, however, may also be related to other factors, such as anxiety, fatigue, increased thyroid function, or inherited trait. Two other physical examination findings, neck rigidity and bradykinesia, were found only among workers with more than 15 years in production, suggesting that these findings could be related to work exposures. However, the numbers of affected workers were too few to allow meaningful statistical analysis.

Work in the EMD plant before the 1987 fire, eating in the work area, and using tobacco in the work area had been entered into the statistical models because they were factors that could have increased workers' exposures to manganese and, as a result, could have contributed to the risk for disease. Although these variables do not independently represent manganese exposure, they were more strongly associated with four symptom indices than was the surrogate for manganese exposure—work in the EMD plant. They could have represented other risk factors, including those unrelated to work. The outcome variables, such as the symptoms in the symptom indices, could also have represented biological processes besides manganese toxicity. Because this study was limited to work in the EMD plant, other risk factors and biologic processes that could explain the symptoms cannot be determined from it.

Work in the ferromanganese furnace departments was used as a surrogate for exposure to manganese dust and fume outside the EMD plant. Therefore, the associations between work in the ferromanganese furnace departments and the symptom indices for concentration, memory, and motor function could indicate that exposure to manganese dust and fume in those departments might have contributed to the symptoms. However, different job categories within the furnace departments, where exposures to other neurotoxins besides manganese might have occurred, had been combined for the analyses. Stratification by job title to further investigate this hypothesis would not have been meaningful because of the small number of participants in this study.

Although this study did not show a definite association between work in the EMD plant and adverse health outcomes among groups or workers, the possibility that an individual's health was affected by work exposures has not been ruled out. Such a determination is beyond the scope of this investigation. In general, negative findings in statistical analyses do not necessarily establish that an individual's health problem is or is not work-related. The results provide the statistical probabilities of finding exposure-outcome relationships within the exposure categories under study. They are affected by assumptions made for each exposure category (such as using the highest exposure category ever worked in as a surrogate for actual exposure to manganese dust). These assumptions do not necessarily reflect exposures or conditions experienced by an individual. An individual's manganese exposure could have been higher (or lower) than the group's exposure. Conversely, a statistical association does not necessarily mean that an individual's abnormal health outcome is caused by the exposure. Any number of other factors (not necessarily related to work) could have contributed to the development of an individual's health problems.

The following limitations of the study should be considered when interpreting the results. Quantitative estimates of past or cumulative exposures could not be made for individual participants or job titles because of insufficient historical air sampling data. The job titles used within exposure categories do not necessarily reflect actual exposures because of the changes made when the plant was renovated in 1987 and the improvements in engineering controls made over time. Also, many employees, particularly production and support workers, worked in more than one exposure category. Cumulative exposure might not have been accurately reflected by the exposure categories used in the analyses. In addition, many workers, especially those in the support category (such as mechanics), had exposures to potential neurotoxins (such as organic solvents) besides manganese.

The study was also limited by the low participation rate of former employees (44%). Of eligible production workers, participants tended to have worked more years (mean 7.2 yrs) than nonparticipants (mean 3.6 yrs) (Table 12). Of eligible workers who had worked in the ferromanganese furnace departments, participants tended to have worked fewer years (mean 5.1 yrs) in those departments than nonparticipants (mean 9.3 yrs).

Although the results of the NIOSH industrial hygiene surveys showed that current exposures remain below the NIOSH, OSHA, and current ACGIH evaluation criteria, 31% of the full-shift PBZ measurements were above the proposed ACGIH TLV of 0.2 mg/m^3, which is intended to reduce the respiratory symptoms, preclinical psychomotor abnormalities, and decreased fertility that have been associated with exposures within the current TLVs [Lauwerys et al., 1985; Roels et al., 1987b; ACGIH, 1995b]. Although the proposed ACGIH TLV and recommendations made by Roels et al. [1987b, 1992] and Wennberg et al. [1991] are for total manganese, they are probably more protective than the Eveready internal guideline for limiting workers' exposure to respirable manganese to less than 0.3 mg/m^3.

RECOMMENDATIONS

The following recommendations are provided to reduce worker exposure to manganese, decrease the potential risk for manganese toxicity, and to improve the overall occupational health program.*

1. Potential sources of exposure (such as system leaks or routine emission sources) should be periodically reexamined, and the adequacy of control systems should be reassessed. Installation of additional process enclosures and local exhaust ventilation will be required to reduce manganese exposures below the proposed ACGIH full-shift exposure TLV of 0.2 mg/m^3. Local exhaust ventilation design improvements may be warranted to further reduce the generation of manganese dust at the sources of emissions. In addition, the company should consider an upgrade of the general (dilution) ventilation system and increased filtration of recirculated air in some locations to reduce background levels of manganese The latest edition of the ACGIH Industrial Ventilation Manual should be consulted when designing or redesigning local exhaust ventilation systems [ACGIH, 1995a].

2. Local exhaust ventilation should be provided at the bulk bag assemble station and where leaching area "seed" manganese bags are disposed.

*Some of these recommendations were made in August 30, 1990, at the end of the initial site visit, and in a letter to the company dated November 1, 1990.

3. Reusable bags should always be cleaned before reuse.

4. Dry sweeping of manganese-containing dust should be eliminated. If practical, wet clean-up methods should be used for environmental dust removal. Any dry clean-up methods should be performed by a vacuum system equipped with a high efficiency particulate air (HEPA) filter.

5. All equipment should be HEPA-vacuumed prior to preventive or corrective maintenance, especially before welding or torch cutting.

6. A respiratory protection program should be implemented as a temporary preventive measure until additional engineering controls are installed to reduce employee exposures to below the proposed ACGIH TLV of 0.2 mg/m^3 and as a permanent preventive measure if further reduction of exposures by engineering controls is not feasible.

7. Respirator users should be clean shaven in the area of the face-piece seal.

8. Tobacco smoking in areas of potential manganese exposure, even if these locations are outdoors (such as the ore shed), should be prohibited. Manganese exposure may be increased by the use of contaminated tobacco products.

9. Cigarettes and food should not be allowed in any dusty areas because of the possibility of manganese contamination. Workers should be instructed to wash their hands before handling cigarettes or food to prevent contamination and the subsequent inhalation or ingestion of manganese-contaminated dust.

10. Employees should be trained about the adverse health effects of manganese exposure and should be encouraged to report any symptoms consistent with manganese toxicity. Employees with such symptoms should be evaluated by medical personnel who have knowledge of the adverse health effects of manganese exposure. These employees' work areas should be examined for sources of overexposure.

11. Eveready should continue to perform industrial hygiene monitoring and record keeping to identify high exposure locations and job tasks, to evaluate the effectiveness of new engineering controls, and to assess work methods that can be altered to reduce exposure potential.

Glossary of medical terms

bradykinesia extreme slowness of movement, see *hypokinesia*
fertility ability to produce children
gait disturbance difficulty walking

hypokinesia decreased movement or slowness of movement, see *bradykinesia*
impairment weakening, damage, or deterioration as a result of injury or disease
libido sexual desire, manifestation of the sexual drive
manganese toxicity, chronic a Parkinson-like neurologic syndrome related to manganese overexposure
mask-like facies a smooth and expressionless face, one of the abnormalities that can be seen in patients with Parkinson's disease or Parkinson-like syndrome
muscle rigidity decreased range of movement as a result of increased muscle tone
neurotoxin an agent that damages or causes malfunction of the nervous system
Parkinson's disease a movement disorder related to abnormalities in a specific part of the brainstem (substantia nigra), characterized by slowness of movement, muscle rigidity, and other abnormalities of movement
Parkinson-like disease or syndrome one of a number of neurologic illnesses, such as chronic manganese toxicity, whose clinical presentation is similar to that of Parkinson's disease
postural instability difficulty standing
preclinical finding mild abnormality that would not typically be looked for or recognized as a medical problem
psychomotor relating to the production of voluntary muscle movements
rigidity see *muscle rigidity*
subclinical see *preclinical findings*

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2. Ralston Purina Company, Eveready Battery Company
3. U.S. Department of Labor, OSHA, Region V

In order to comply with the NIOSH regulation that affected employees shall be notified about the determination of this health hazard evaluation (CFR, Title 42, Part 85, Section 85.11), the employer shall post copies of this report in a prominent place accessible to the employees for a period of 30 calendar days.