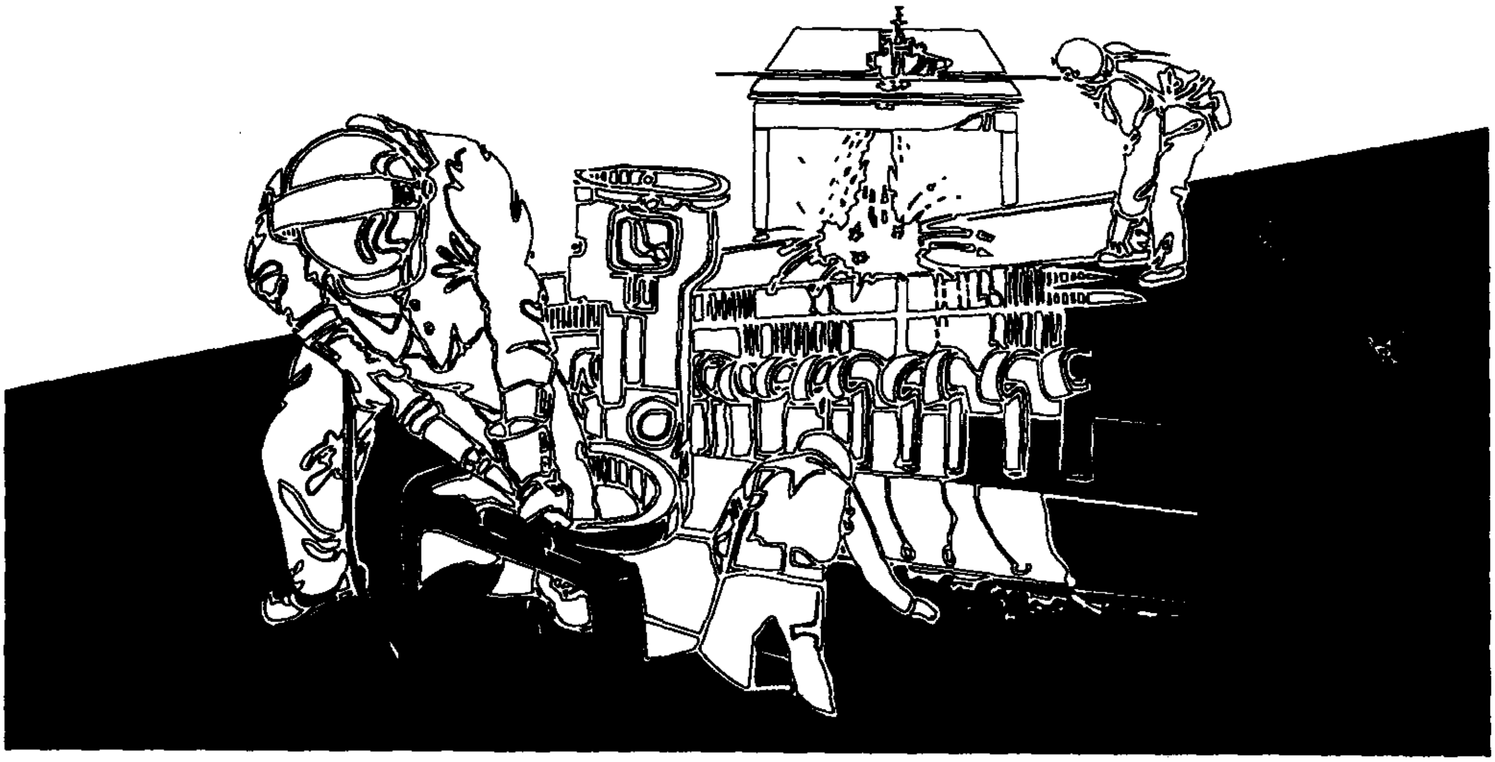
NIOSH

HEALTH HAZARD EVALUATION REPORT

HETA 87-402-2145
LCP CHEMICALS AND PLASTICS, INC.
BRUNSWICK, GEORGIA



U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health

CDC
CENTERS FOR DISEASE CONTROL

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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I. SUMMARY

On September 9, 1987, the National Institute for Occupational Safety and Health (NIOSH) received a request from the International Chemical Workers Union Local 716 (ICWU) to evaluate worker exposure to mercury, chlorine, and hydrochloric acid (HCl) at LCP Chemicals and Plastics, Inc. (LCP) in Brunswick, Georgia.

On October 13-14, 1987, and April 26-27, 1988, investigators from NIOSH conducted concurrent industrial hygiene and medical evaluations of workers exposed to the above chemicals in the chlorine cell rooms and adjacent areas of the plant. NIOSH industrial hygienists and a health physicist returned on October 19-21, 1988, to perform measurements of the static magnetic fields produced in the cell rooms at LCP.

During the initial visit, area sampling for hydrochloric acid (HCl) was performed using NIOSH Method 7903, with the samples analyzed for chloride ions by ion chromatography. One of the area samples collected near the acid burners had a concentration of HCl above the Occupational Safety and Health Administration's (OSHA) permissible exposure limit (PEL), the NIOSH recommended exposure limit (REL), and the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) of 5 parts per million (ppm). Area sampling for chlorine in the cell rooms was performed using OSHA Method VI-15, with the samples analyzed for chloride ions by ion selective electrode. Of the seven air samples collected for chlorine, one had a concentration above the OSHA PEL, NIOSH REL, and ACGIH TLV of 0.5 ppm. Personal breathing zone air sampling for mercury was performed on cell room workers using the 3M Brand Mercury Vapor Monitoring System 3600A. All 17 samples collected had mercury concentrations above the OSHA PEL, NIOSH REL, and ACGIH TLV of 50 micrograms per cubic meter of air ($\mu g/m^3$).

During the second site visit, a similar industrial hygiene sampling protocol was conducted during the first and second shifts to better characterize exposures in the cell rooms. Fourteen of 33 area air samples for chlorine showed concentrations above the OSHA PEL, NIOSH REL, and ACGIH TLV of 0.5 ppm. In fact, six of these time weighted average (TWA) concentrations were above the short term exposure limit of 1.0 ppm. Area and personal breathing zone air sampling for mercury was conducted using NIOSH Method 6009, and the samples were analyzed by cold vapor atomic absorption spectroscopy. Six of 29 personal samples for mercury had concentrations above the OSHA PEL, NIOSH REL, and ACGIH TLV of 50 $\mu g/m^3$ The average mercury exposure concentration for all 29 cell room workers participating in this survey was

31.7 $\mu g/m^3$. Area air sampling also detected mercury concentrations in the cell rooms and in other areas of the plant.

The intensity of magnetic fields in both cell rooms ranged from 0 to 500 Gauss. The highest level, 500 Gauss, was obtained at the handles near the caustic boxes. The exposure levels on top of the cells and at other selected spots around the cells reached 200 Gauss. Areas near the control panels between the cell banks gave values of 100-150 Gauss. All other locations gave values in the 20-50 Gauss range. These measurements were below the ACGIH recommended exposure limit of 600 Gauss whole body, and 6000 Gauss to the extremities based on daily time weighted average exposures.

The mean urine mercury level among 58 LCP workers was 140 micrograms of mercury per gram creatinine (μg Hg/g creatinine), with a range of 2 to 689. Half the workers tested had urine mercury values in excess of a World Health Organization study group's recommended level of 50 μg Hg/g creatinine; the highest levels were seen in cell room workers. Despite these high levels, urine mercury levels were not associated with neurobehavioral symptoms reported on a self-administered questionnaire or with neurologic signs on physical examination. These measures of health effects may not have been adequately sensitive to detect subtle abnormalities associated with mercury exposure.

The NIOSH investigators conclude that a health hazard does exist from exposure to mercury and chlorine in and around the cell rooms at LCP Chemicals and Plastics, Inc. This conclusion is based on the number of personal breathing zone and area air concentrations of mercury and chlorine above their respective evaluation criteria, and the high concentrations of mercury in the urine of the tested workers. In addition, the NIOSH investigators conclude that a potential health hazard does exist from acute exposure to hydrochloric acid in the acid burners area. Based on measurements made during the surveys, the NIOSH investigators conclude that there are no overexposures to the static magnetic fields in the cell rooms. Recommendations are made in Section VIII of this report to protect workers from exposure to mercury, chlorine, and hydrochloric acid.

KEYWORDS: SIC 2812 (Industrial Inorganic Chemicals, Alkalies and Chlorine), SIC 2819 (Industrial Inorganic Chemicals, Not Elsewhere Classified), mercury, chlorine, hydrochloric acid, urine mercury levels, biological monitoring, static magnetic fields, chlor-alkali plant.

II. INTRODUCTION

On September 9, 1987, the National Institute for Occupational Safety and Health (NIOSH) received a request from the International Chemical Workers Union Local 716 (ICWU) to evaluate worker exposure to mercury, chlorine, and hydrochloric acid (HCl) at LCP Chemicals and Plastics, Inc. (LCP) in Brunswick, Georgia.

On October 13-14, 1987, and April 26-27, 1988, investigators from NIOSH conducted concurrent industrial hygiene and medical evaluations of workers exposed to the above chemicals in the chlorine cell rooms and adjacent areas of the plant. NIOSH industrial hygienists and a health physicist returned on October 19-21, 1988, to perform measurements of the static magnetic fields produced in the cell rooms at LCP.

The data and results from the first site visit were reported to LCP and the union on March 11, 1988. This report contained the results from area air sampling for HCl and chlorine, personal breathing zone air sampling for mercury, and medical interviews conducted with 13 workers. Recommendations were made to LCP for the modification of their biological monitoring program for mercury in urine. On September 1, 1988, the results from the second site visit were reported to LCP and the union, including data from exposure assessments for mercury and chlorine, and from biological monitoring for mercury in cell room workers. The NIOSH investigators made several recommendations to protect workers from hazardous exposure to mercury; including respiratory protection for potentially overexposed workers, methods to prevent the contamination of workers' street clothing with mercury, and local exhaust ventilation for the mercury pump repair area. The data from the third site visit and evaluation of the exposure to static magnetic fields were issued on August 30, 1989, along with recommendations to purchase magnetic field monitoring instruments and non-magnetizable tools, to post warning signs and inform the workers of their exposure to these fields, and to investigate the hazards associate with welding magnetized surfaces. Finally, the results from the medical questionnaire and physical examinations were issued to LCP and the union on March 5, 1990.

III. BACKGROUND

The LCP Chemicals and Plastics facility in Brunswick is a chlor-alkali plant which employs approximately 124 production workers. The main products of the plant are chlorine gas, sodium hydroxide (caustic soda), and sodium hypochlorite (bleach).

The main production areas of the plant are the two cell rooms, which manufacture large quantities of chlorine gas. The cell rooms are two story rectangular structures which are located parallel to each other. The first story of these rooms is an open air area with a concrete floor to catch mercury spills. The cells are located on the second floors which contain two parallel rows of 25 cells, with each cell labelled with a unique identification number. A typical chlorine cell actually consists of two cells: an electrolyzer, in which saturated brine containing 25% sodium chloride by weight is decomposed, and a denuder cell. The two cell rooms are connected by an elevated walkway, which also supports the four acid burner units.

As its name implies, the electrolyzer is an electrolytic cell consisting of a titanium-based anode and an inorganic mercury cathode. The electrolytic cells in this facility utilize 84,000 amperes DC current. As brine passes between the electrodes, chlorine gas is liberated at the anode and is discharged to a purification process. Sodium metal is liberated at the cathode, immediately reacting with the mercury to form an amalgam. From the electrolyzer, the amalgam is fed into the denuder cell, where it reacts with water to release the mercury and to form sodium hydroxide and hydrogen. The sodium hydroxide may be shipped as a final product, or reacted with chlorine gas to produce sodium hypochlorite. Since 1981, the facility has also produced hydrochloric (muriatic) acid.

There are approximately forty workers in four different job categories in the cell rooms: mercury handlers, who add mercury to the cells and handle the frequent mercury spills and/or leaks; cell operators, who monitor the operation of the cells and perform quality control tests; cell assembly workers, who maintain the cells, frequently dismantling and rebuilding individual cells; and cell room foremen, who supervise cell room activities for the shift. Outside the cell rooms, there are jobs involving production of brine and bleach, tank car loading and maintenance, and general labor. Maintenance mechanics and electricians work on jobs throughout the plant.

IV. EVALUATION DESIGN AND METHODS

A. Industrial Hygiene

The industrial hygiene study consisted of on-site surveys at LCP during the previously given dates. On the first site visit (October 13-14, 1987), personal breathing zone air sampling for mercury was performed using passive monitoring badges, and area air sampling was performed for hydrochloric acid and chlorine. Mercury exposure assessments were conducted on workers in the cell rooms in the following job titles: mercury handlers, cell room operators, cell room assembly and maintenance personnel, and cell room foremen. The acid burners, which utilize the HCl, are outside and adjacent to the cell rooms. Workers are infrequently in the acid burner areas and only for short periods of time. The most common task performed in these areas is the collection of HCl from the acid burner sample stations for quality control tests. Because of this, and the fact that HCl is typically an acute health hazard, area air samples were used to estimate the worst-case exposure scenario. Workers in the cell rooms are routinely exposed to chlorine during the entire workshift. Since the sampling device (impingers) contain a corrosive liquid, i.e. sulfamic acid, the NIOSH industrial hygienists chose, for safety reasons, to obtain area air samples instead of personal breathing zone air samples. During the second site visit (April 26-27, 1988), the personal breathing zone air monitoring for mercury was repeated using an active sampling technique, along with area air sampling for chlorine in the cell rooms. Finally, the third site visit (October 19-21, 1988) consisted of an evaluation of exposure to the static magnetic fields in the cell rooms. The specific methods used to assess exposure during these site visits are discussed below.

1. Mercury

Both passive and active air sampling techniques were used to determine mercury exposures in the cell room workers. Passive air sampling was performed using the 3M Mercury Vapor Monitoring System 3600A, which is designed for use in the chlor-alkali industry. After removing the badges from the provided pouches, the badges were attached to the workers' lapels. After the completion of sampling, the badges were returned to the pouches, and the samples were mailed to 3M for analysis.

Active air sampling for mercury was performed according to NIOSH Method 6009.[1] Sample air was drawn through SKC Hydrar mercury sorbent tubes using calibrated, battery-powered pumps. These samples were desorbed with a solution of nitric and hydrochloric acids and analyzed for mercury by cold vapor atomic absorption spectroscopy. The limit of detection (LOD) for this method was 0.004 μg per sample; the limit of quantitation (LOQ) was 0.015 μg per sample.

2. Hydrochloric Acid

Area air sampling for HCl was performed using NIOSH Method 7903, with sample air being drawn through a sorbent tube containing washed silica gel (Orbo-53, manufactured by Supelco, Inc.) using calibrated, battery-powered pumps.[1] The samples were desorbed with a bicarbonate/carbonate buffer solution, and analyzed for chloride ions using ion chromatography. The LOD for this method was 0.4 μg/sample; the LOQ was 1.2 μg/sample.

3. Chlorine

Area air sampling for chlorine was performed using OSHA Method VI-15, in which chlorine was collected by drawing air through impingers containing a 0.1% sulfamic acid solution.[2] After collection, the samples were diluted to 25 milliliters (ml) and a 3-ml aliquot was taken for analysis. Color was developed by adding 0.5 ml of acid reagent and 0.5 ml of potassium iodide, and the sample aliquots were analyzed by ion selective electrode. The LOD was 3 μg/sample; the LOQ was 12 μg/sample.

4. Static Magnetic Fields

The magnetic fields were measured with a Walker Scientific model MG-50P gauss meter that incorporated both axial and transverse probes. All readings were recorded in the root mean squared mode (RMS) due to the presence of a composite AC and DC fields. The gauss meter works on the Hall effect principal and is designed to measure both DC and AC (RMS) magnetic fields over the range from 0.1 to 20 kilogauss. The magnetic sensor had been calibrated by the manufacturer within six months of use. Background levels were obtained outside the building at distances greatly removed from the cell rooms. Measurements were made in the walkways around the cells in both cell rooms, on the top and bottom of the cell banks, on the floor below the cell room, in the office and rest areas immediately adjacent to the cell rooms, and in the roadway outside the cell room facility (background). Most measurements were taken at a distance typical of occupational exposure (3 feet away and 3 feet above the floor); however, in a few circumstances results were obtained at closer distances.

B. Medical

1. October 13-14, 1987 Site Visit

A NIOSH physician conducted medical interviews with 13 workers, specifically asking about symptoms typically associated with mercury poisoning, such as tremor, gingivitis, or erethism (the personality changes often found in cases of mercury intoxication, including nervousness, irritability, and/or paranoia). The NIOSH physician reviewed LCP Chemicals and Plastics' program for urine mercury screening, including the methods of analysis, the reference limits used to define "normal," and the procedures followed when a worker's measured urine mercury level exceeds the acceptable level. The physician also reviewed the records for urine testing to the time of the visit.

2. April 26-27, 1988 Site Visit

All mercury-exposed workers (cell room workers, mercury handlers, production operators) and a random sample of all other employees were invited to participate in the medical investigation; workers participated by informed consent. Sixty-three of 65 eligible workers (97%) participated; 61 participating workers completed a questionnaire which asked details of medical history, dietary intake, and health symptoms. Questions particularly stressed neurologic and behavioral symptoms. Participating workers also underwent a screening neurologic examination conducted by either of two NIOSH physicians.

Fifty-eight workers also contributed urine specimens for analysis of urine mercury levels using creatinine correction for dilution. Two workers who contributed postshift urine specimens did not complete questionnaires or undergo physical examination, and 5 workers who completed questionnaires and received physical examinations did not furnish urine specimens. Urine samples were collected from workers in all production areas. When the samples were analyzed by laboratories at the Center for Environmental Health and Injury Control of the Centers for Disease Control in Atlanta, levels of mercury and creatinine were measured in each sample. Creatinine is a substance normally excreted by the kidney in an amount which is fairly constant from day to day. It was used here to correct for any dilution which may have resulted from normal physiologic variations in kidney excretion of water. Mercury levels are therefore reported as micrograms of mercury per gram of creatinine (μg Hg/g creatinine).

The results of urine sampling for biological monitoring of mercury absorption were reported following analysis; individual workers received private reports of their own urine mercury level, while management and union representatives received aggregate data.

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 a number of chemical and physical agents. These criteria are intended to suggest levels of exposure which most workers may be exposed up to 10-hours per day, 40-hours per week, for a working lifetime, without experiencing adverse health effects. It is, however, important to note 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 level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus, potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH criteria documents and recommendations, including recommended exposure limits (RELs), 2) the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), and 3) the U.S. Department of Labor, OSHA permissible exposure limits (PELs). The OSHA standards may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended standards, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required by the Occupational Safety and Health Act of 1970 to meet those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA, where there are recognized toxic effects from high short-term exposures.

B. Mercury

Mercury can enter the body through the lungs by inhalation, through the skin by direct contact, or through the digestive system. Occupational exposure most commonly occurs through inhalation of mercury vapor, where about 80% of the inhaled mercury will be absorbed.[3]

Acute or short-term exposure to high concentrations of elemental mercury causes erosive bronchitis, bronchiolitis, and diffuse interstitial pneumonia.[4] Symptoms include tightness and pain in the chest, cough, and difficulty breathing. Other acute effects include nausea, abdominal pain, vomiting, diarrhea, headache, and inflammation of the mouth and gums.[5]

Chronic or long-term exposure to mercury can result in symptoms of weakness, fatigue, loss of appetite, loss of weight, gingivitis, metallic taste, disturbance of gastrointestinal functions, and discoloration of the lens in the eye. Early symptoms of central nervous system effects include increased irritability, loss of memory, loss of self-confidence, emotional instability with depressive moods, and insomnia. The neuropsychiatric term for this complex is erethism. At higher exposure levels, fine tremor and coarse shaking can appear, as well as severe behavioral changes including delirium and hallucination. Tremor progresses in severity with duration of exposure. Although the symptoms in cases of slight poisoning regress and disappear when exposure has ceased, nervous system effects may persist in cases due to long-term exposure. Mercury exposure has also been associated with effects of the kidney, including development of nephrotic syndrome in extreme cases.[3,4,6]

Reproductive effects of exposure to metallic mercury vapor have been studied in animals and humans. Experimental exposure of female rats to mercury vapor has been reported to cause changes in the estrus cycle (the reproductive cycle), decreases in the number of offspring born to each female, and increases in the number of deaths among offspring. Transfer of mercury across the placenta to the fetus has been demonstrated in rats.[7] Investigations of female workers occupationally exposed to mercury vapor have indicated that exposed women had higher rates menstrual abnormalities and of complications in pregnancy and labor than did non-exposed women and other studies have shown that mercury can be transferred in breast milk. In a case report of men exposed to hazardous levels of mercury vapor, signs of chronic mercury poisoning were accompanied by reduced libido.[7] Because of concern for reproductive hazards, the World Health Organization convened a working group to investigate this issue. Considering the available data on adverse reproductive outcomes associated with mercury exposure, the working group was unable to recommend a specific limit for the exposure of women of childbearing age to mercury.[4]

Elemental mercury is gradually excreted from the body; the primary routes of excretion are through the urine and, to a slightly lesser degree, the feces. Elimination will persist for months following cessation of exposure. The biologic half-life of mercury in the human body is approximately 40 days.[6,8]

Epidemiologic studies have shown that the mercury concentration (per gram of creatinine) in urine can be used as an indicator of mercury exposure in exposed workers when studied in groups. Individual variations in mercury uptake and metabolism, however, may result in different urine mercury values among individual workers with similar exposures.[3] Most epidemiologic studies have shown, at most, a weak association between urine mercury levels and adverse health effects in individuals. The reason for this is poorly understood, although it is possible that mercury levels in urine do not accurately reflect levels in the brain, where neurologic toxicity occurs. However, because high urine mercury levels in a group of workers are indicative of prolonged exposure to high concentrations of mercury vapor, high levels in a group indicate a greater risk of mercury poisoning and should be avoided.[3]

People without occupational exposure to mercury generally have a urine mercury level of less than 5 μg Hg/g creatinine. The urine mercury level of an occupationally exposed person depends on the level of exposure, the timing of the urine collection relative to the exposure, and the overall concentration of the urine (which depends, in part, on the amount of water excreted by the kidney during the time period that the urine sample represents). A study group of the World Health Organization (WHO) has recommended that a level of 50 μg Hg/g creatinine not be exceeded.[4] In 1990, the ACGIH proposed a Biological Exposure Limit (BEI) for mercury in urine of 35 μg/g creatinine. Presently, the BEI for mercury is in the ACGIH's "Notice of Intent to Establish List". If after two years, no presented evidence questions the appropriateness of this standard, then the value will be considered for inclusion in the "Adopted" list.[9]

The OSHA PEL and ACGIH TLV for mercury are 8-hour TWA exposure levels of 50 $\mu g/m^3$.[9,10] The NIOSH REL is 50 $\mu g/m^3$ for up to a 10-hour exposure, 40-hours per week.[11]

C. Chlorine

At room temperature, chlorine is a greenish-yellow gas with an odor threshold of 0.02 parts per million (ppm). There is some evidence that olfactory fatigue may occur at low concentrations and that a tolerance is built-up in exposed workers. Inhalation of chlorine gas produces irritation of the upper respiratory tract, which is characterized by burning sensations in the nose and mouth, coughing, chest pain, choking, nausea, headache, and dizziness. Severe breathing difficulties may occur several hours after the initial exposure. Exposure to higher concentrations can cause pulmonary edema, pneumonia, and even death. Chlorine is also irritating to the eyes and skin, producing excessive tearing (lacrimation) and dermatitis upon contact.[12-15] Presently, the OSHA PEL and ACGIH TLV for chlorine are 0.5 ppm for an 8-hour TWA exposure, and 1 ppm as a 15-minute STEL.[9,10] The NIOSH REL is 0.5 ppm for up to a 10-hour TWA exposure, and 1 ppm as a 15-minute STEL.[11]

D. Static Magnetic Fields

Exposure to static magnetic fields has been linked to slight increases in blood pressures, improper operation of artificial cardiac pacemakers, movement of implanted metal objects, rotation of sickle cells, and disturbances in the length of circadian cycles.[16,17] Very little epidemiological work has been performed in steady fields, and what has been published for time-varying fields is contradictory. It is quite obvious that more work is necessary, and until the work has been completed, exposure guidelines are at best incomplete.

There have been no enforceable occupational health limits set for static magnetic fields. In 1971, the Stanford Linear Accelerator Center proposed values of 2000 to 20,000 Gauss, depending on time and exposure area of body, for an upper limit based on lack of complaints.[18] In 1979, the Department of Energy, based on known biological effects that had been reported, established more conservative limits of up to 20,000 Gauss.[18] Presently, the ACGIH recommends that routine occupational exposure to static magnetic fields not exceed 600 Gauss whole body, or 6000 Gauss to the extremities based on a daily TWA exposure. A flux density of 20,000 Gauss is recommended as a ceiling value. The ACGIH further states that workers with implanted cardiac pacemakers not be exposed to levels above 10 Gauss, and recommends that caution be taken when exposing workers with implanted ferromagnetic devices, e.g., suture staples, aneurysm clips, prostheses, etc.[9]

VI. RESULTS AND DISCUSSION

A. Industrial Hygiene Study

1. Hydrochloric Acid and Chlorine

Environmental air sampling results for hydrochloric acid and chlorine are presented in Tables 1, 2, 3, and 4. From Table 1, one of the eight area air samples had a concentration above the OSHA PEL, NIOSH REL, and ACGIH TLV of 5 ppm. The 10.4 ppm concentration was found at the sample station for acid burners 2 and 4, which is infrequently visited by workers. The NIOSH investigators observed that workers in or passing through the area could get a substantial exposure, depending on the direction and speed of the prevailing wind. Most workers observed in this area carried half-face respirators with acid mist cartridges attached to their belt and donned these respirators when acrid vapors were detected. The masks and cartridges were not enclosed in a plastic bag, increasing the possibility of contamination prior to use.

Table 2 shows that most of the chlorine levels measured in the cell rooms on October 14, 1987 were below the NIOSH REL of 0.5 ppm. Only the chlorine level near saturation pump #322 was above the NIOSH REL, but this area was seldom visited by workers. The average chlorine concentration measured in seven samples during this site visit was 0.10 ppm.

Extensive area air sampling for chlorine was conducted during the April 26-27, 1988 site visit, with the data from this first and second shift sampling shown in Tables 3 and 4, respectively. Three of the seventeen (18%) first shift samples had concentrations above the consensus OSHA, ACGIH, and NIOSH exposure limits of 0.5 ppm, with the first shift average chlorine concentration in 17 samples being 0.28 ppm. In addition to this, 11 of the 16 (69%) second shift chlorine concentrations were above the 0.5 ppm exposure limits. It is interesting to note that 6 of the 33 (18%) total TWA area air samples taken during first and second shift had concentrations above the OSHA, ACGIH, and NIOSH STEL of 1.0 ppm, which is based on any 15-minute exposure period during a workshift. Though area air sampling cannot be used to determine a worker's personal exposure, considering the observed area concentrations of chlorine, the NIOSH investigators surmise that worker overexposure to chlorine in the cell rooms could occur. The NIOSH investigators could not ascertain why the average chlorine concentrations were higher during second shift than during first shift (averages of 0.83 ppm versus 0.28 ppm).

2. Mercury

As shown in Table 5, all 16 of the personal breathing zone air samples for mercury had concentrations above the OSHA, NIOSH, and ACGIH exposure limits of 50 $\mu g/m^3$. As previously mentioned, this air sampling was performed using passive sampling badges. It was evident from the data collected that cell assembly workers and mercury handlers had the highest mercury exposures. The average mercury exposure level measured during this site visit was 132 $\mu g/m^3$.

Because of the high environmental mercury levels measured during the initial visit, NIOSH industrial hygienists returned to LCP Chemicals and Plastics on April 26-27, 1988. During this second site visit, the NIOSH industrial hygienists used an active air sampling method to assess mercury exposures.

The results of the personal breathing zone air sampling for mercury during first and second shift appear in Tables 6 and 7, respectively. From the tables, 6 of the 22 (27%) personal samples from first shift, and none of the personal samples from the second shift, were above the NIOSH, OSHA, and ACGIH exposure standards of 50 $\mu g/m^3$. As with the passive air sampling data in Table 5, the highest average exposure concentrations were measured in mercury handlers and cell assembly workers. The average mercury exposure levels per shift were 42.4 $\mu g/m^3$ for 22 first shift workers and 28.5 $\mu g/m^3$ for 7 second shift workers. It should be noted that no cell assembly workers or mercury handlers were employed during second shift, which could account for the lower average exposure when compared to first shift workers.

Data from the area air sampling for mercury (Table 8) showed several areas with substantial mercury contamination, including the laundry room, the locker room, the first aid room, and the break-rooms and restrooms in each cell room. A possible source of this contamination was mercury contamination of workers' clothing. The range of mercury concentrations (in $\mu g/m^3$) in the cell rooms were as follows: 20.9 to 37.9 in the break rooms, 5.9 to 34.4 from the Assembly/Maintenance areas, 16.5 to 59.0 from the center aisle of the rooms, and 13.9 and 17.6 in each of two restrooms. Finally, a single mercury concentration of 101.3 $\mu g/m^3$ was measured in the open area under cell room 2. As with the HCl levels in the acid burner areas, exposure to mercury in this area is dependent on the speed and direction of the wind.

3. Static Magnetic Fields

While both the axial and transverse probes were used in the evaluation of static magnetic fields, very little difference was noted between the two probes. Therefore, for purposes of this evaluation, only the axial results are given.

The intensity of magnetic fields in both cell rooms ranged from 0 to 500 Gauss. The highest level of 500 Gauss was obtained at the handles near the caustic boxes. These handles were point source magnetic fields that could easily be shielded and greatly reduced. The exposure levels on top of the cells and at other selected spots around the cells reached 200 Gauss. All other locations gave values in the 20-50 Gauss range. Both cell rooms were quite similar in spatial distribution of the magnetic field, and each contained an area near the control panels between the cell banks that gave a value of 100-150 Gauss.

The results found in the evaluation of static magnetic fields can be compared to some extent with the results reported by Marsh.[19] In that study, which was performed in a similar environment, the average static magnetic field level was 7.6 millitesla (mT) and the maximum field was 14.6 mT. Using the conversion factor of 1 Tesla = 10,000 Gauss, the average field strength was 76 Gauss and the maximum field strength was 146 Gauss.

B. Medical Study

1. October, 1987 visit

None of the 13 workers interviewed described symptoms typically associated with mercury poisoning, such as tremor, gingivitis, or erethism (the personality changes often found in cases of mercury intoxication, including nervousness, irritability, and/or paranoia).

2. April, 1988 visit

Despite the absence of symptoms reported by workers during the initial visit, additional medical investigations were conducted because of the high environmental mercury levels measured.

a. Urine mercury levels and job classification

Participating workers were divided into four exposure groups on the basis of their current job category. Summary statistics for all groups tested are reported in Table 9. The 24 workers in all cell room jobs had the highest creatinine-corrected urine mercury values (mean 281 μg Hg/g creatinine, range 22-690). Within this group, the 12 cell assembly workers had an average urine mercury level of 311 μg Hg/g creatinine, the highest average urine mercury level of all groups at LCP. The 10 cell operators had an average level of 258 μg Hg/g creatinine, while the 2 cell foremen averaged 214 μg Hg/g creatinine. One cell room worker who did not report a specific job category had a urine mercury of 9 μg Hg/g creatinine.

The 2 mercury handlers had the next highest levels with a mean urine mercury of 48 μg Hg/g creatinine (range 39-57). The 12 maintenance personnel and mechanics had a mean urine mercury of 26 μg Hg/g creatinine (range 5-38).

Some personnel employed in other categories that reportedly did not involve mercury exposure (i.e., brine operator, tank car, etc.) had surprisingly high urine mercury levels. Although the mean urine mercury level for the 19 workers in this category was only 38 μg Hg/g creatinine, levels ranged from a low of 2 to a high of 159; six workers had urine mercury levels exceeding 50 μg Hg/g creatinine. All six, however, reported that their job immediately prior to the current job was a cell room job. The three workers with the highest urine mercury levels (88 to 159 μg Hg/g creatinine) had left cell room jobs within the preceding 2 months. Thus, their urine mercury levels were likely attributable to their exposures in their previous job positions. The other three workers (with urine mercury levels of 50 to 70 μg Hg/g creatinine) had not worked in the cell room for at least a year. Because the biological half-life of mercury (the time it takes the body to excrete half the mercury it has absorbed) is approximately 58 days (range 35 to 90 days in one study), it is less likely that these high urine mercury values reflect exposure to high environmental mercury levels in previous job positions.[5] Additional exposure to mercury from contamination by exposed workers may have occurred in the communal areas (break room and locker room) where NIOSH industrial hygienists measured airborne mercury levels of 21 to 38 μg Hg/m^3. It is also possible that these "unexposed" workers may have had occupational exposure to mercury, either through unrecognized exposure to mercury or through unreported time spent in high exposure areas/jobs.

b. Influence of work practices on urine mercury levels

Workers were asked about their use of personal protective equipment and their adherence to hygienic practices at work. Their responses for each work practice were analyzed by stratifying the workers into those working in jobs with low or high mercury exposure; based on job descriptions, mercury handlers and workers in cell room jobs were considered to have high exposure jobs, while maintenance workers, mechanics, and workers employed in other areas of the plant were considered to have low exposure jobs. We compared creatinine-corrected urine mercury values between groups which did and did not report use of personal protective equipment or work practices including the use of filter respirator, cartridge respirator, gloves, or apron, or by whether the person smoked at the work site, ate at the work site, washed his hands before smoking, or washed his hands before eating. These practices were considered in a multivariate analysis-of-variance model which also included high-or-low job exposure category. Only job exposure was significantly related to urine mercury level ($p=0.0001$).

c. Association of urine mercury levels and health symptoms

Workers were asked whether they suffered from any of 42 different health symptoms. In the analysis these symptoms were categorized into 7 symptom groups: fatigue, symptoms of impaired memory, gastrointestinal symptoms, psychiatric symptoms (mood or behavioral symptoms), neurologic symptoms, physical symptoms (rash or abnormal oral mucosa, as reported by the worker), and cardiopulmonary symptoms. A positive response to any question in a symptom group was counted as a positive response for that group.

The questionnaire asked about use of other substances which could affect neurologic symptoms. All respondents denied use of marijuana. Fifty-three respondents said they drank caffeine-containing beverages, while 7 said they did not drink caffeinated beverages.

Responses to questions about alcohol use were often incomplete or contradictory. Of the 63 respondents, 15 (24%) did not answer whether or not they currently drank alcohol, and 27 (43%) did not complete the questions regarding frequency of alcohol use. Respondents gave inconsistent answers about alcohol use; only 30 said they currently drink alcohol-containing beverages, but six of those who denied current alcohol use also said they drank at least 1 to 3 drinks per sitting. These inconsistencies may reflect confusing aspects of the questionnaire. Because the questions about amount of alcohol consumption did not distinguish between present and past use, all analyses concerning alcohol use were limited to respondents reporting current use. Low use of alcohol was defined as: no alcohol consumption at all; 1-3 drinks per sitting 1-3 times/week or less; or 4-6 drinks/sitting less than once per week. All others who reported current alcohol consumption were considered high alcohol consumers. In this analysis, 7 workers were high consumers and 22 were low consumers of alcohol. Because of the inconsistencies in responses to alcohol use questions, this data may not accurately represent alcohol use among workers at LCP.

The effect of urine mercury level, caffeine intake, and alcohol consumption on each symptom was tested by logistic regression. Urine mercury levels were lower in the symptomatic groups than in the asymptomatic groups, but the differences were not statistically significant for any of the health symptoms being considered when caffeine and alcohol were considered.

Because only 27 workers with urine mercury data provided useable responses for alcohol, inclusion of alcohol in the statistical model excluded from consideration 29 other workers who had not answered the alcohol question but had provided urine specimens. The was data therefore also analyzed to test the effect of mercury and caffeine on symptoms without regard for alcohol. In this analysis urine mercury levels were significantly associated with reports of memory symptoms (p=0.025), although the association with caffeine was not significant (p=0.096). However, the association was negative, implying that workers not reporting symptoms tended to have lower urine mercury levels than workers reporting symptoms.

The three symptoms which comprised the "memory" symptom complex were individually analyzed for association with urine mercury levels and caffeine; the analyses were conducted with and without consideration of alcohol. No significant associations were seen when alcohol, caffeine, and urine mercury were considered together. When caffeine and urine mercury were considered alone, there were no significant associations seen between these exposures and the symptom of having one's relatives notice a change in one's memory. The other two symptoms, having problems recalling things or having to write oneself notes as reminders, showed associations similar to the overall memory symptom complex. When the recall symptom was analyzed, the association with urine mercury was significant (p=0.04) but caffeine was not (p=0.14); the association between symptom and mercury level was negative. When the symptom of making notes was analyzed, the association with urine mercury was significant (p=0.05) but caffeine was not (p=0.07); the association between symptom and mercury level was negative.

d. Detection of neurologic signs

Two NIOSH physicians evaluated 61 workers using a neurologic screening examination. Individual tests were not evaluated if the examining physician felt the test result could not be scored as normal or abnormal. Urine mercury results were available for 56 of the participating workers. Results of the screening test and the urine mercury levels appear in Tables 10 and 11, and are listed by category:

1) Eye movements

All 61 workers had intact extraocular movements. Only 1 worker was reported to show a positive lid lag. Three workers were noted to have nystagmus; their mean urine mercury level (79 μg Hg/g creatinine) was lower than but not significantly different from those without nystagmus (133 μg Hg/g creatinine; Student's t test, p=0.56).

2) Tremor

No worker was observed to have a resting tremor. Eight workers had a static tremor; the mean urine mercury level of this group (55 µg Hg/g creatinine) was significantly lower than that of the group without tremor (149 µg Hg/g creatinine; p=0.005). Five workers showed an intention tremor; their mean urine mercury level (91 µg Hg/g creatinine) was lower but not significantly different than that of workers not showing an intention tremor (mean 141 µg Hg/g creatinine; p=0.50).

3) Proprioception and cerebellar function

These tests examine nervous system function associated with balance, coordination, and position. Fifty-five workers of 60 tested had normal finger-to-nose tests; although the abnormal group had a higher mean urine mercury level (254 µg Hg/g creatinine) than the normal group (128 µg Hg/g creatinine), the difference was not significant (p=0.12). Eight of 61 workers had abnormal tests of diadochokinesis (rapid, alternating movements of the hand); the group with abnormal results had lower urine mercury levels (93 µg Hg/g creatinine in group with abnormal response vs. 144 in group with normal response), but the difference was not statistically significant (p=0.40). Only one worker had an abnormal Romberg test (an assessment of reflexes in the spine that are involved in balance). All workers tested had normal heel-to-toe walking tests.

4) Deep tendon reflexes

Sixty-one workers were tested for reflexes in the tendons of the left and right biceps, triceps, patella, and ankle; urine mercury test results were available for 56 of these workers. The results are shown in Table 11. In all cases, urine mercury levels were somewhat higher in the workers with abnormal results, but were not significantly different from the urine mercury levels of workers with normal tests.

VII. DISCUSSION

A. Industrial Hygiene

The breathing zone exposure levels measured in this study indicate that overexposure to mercury is occurring in cell room workers.

Workers in and around the cell rooms were not required to wear any respiratory protection when performing routine work activities. In addition, ventilation is provided to the cell rooms via open doors and openings in the walls. The ceiling fans that are located in the cell rooms are not operated on a frequent basis. Thus, the general dilution air added to the rooms is inconsistent at best. Also, clean-up of mercury spills and leaks in not performed on a regular basis. During the three NIOSH site visits, beads and small puddles of mercury were observed on and around the cells, on the walkways and aisles, in the break rooms and rest rooms, in the cell assembly areas, etc. In some instances, spills of mercury in the cell room were swept into a puddle and allowed to evaporate. Also, the NIOSH investigators observed that some workers stored their work clothes in the same locker as their street clothes. Finally, workers from the cell room are allowed to enter non-mercury-containing areas of the plant without prior changing of clothes. This has resulted in the contamination of other areas such as the first aid room.

The NIOSH investigators conclude that the results obtained on the days of measurement indicate that exposure to magnetic fields at LCP does not represent an occupational hazard. Although measured levels were below the evaluation criteria, there are still certain issues that may require further investigation. Though many measurements taken at locations within the cell rooms yielded higher magnetic fields than other locations, it is our belief that these locations should be not be considered as a health hazard since workers are in these areas for short periods of time. The high field strength levels at the handles for the caustic boxes were significantly reduced by use of handle extensions. This area represents an exposure situation that is unnecessary and can be solved by installing these extensions on all handles. Another issue is that magnetic fields are present due to the DC currents, as well as metal objects that have become permanently magnetized from years of exposure. When the cells are dismantled and rebuilt, additional magnetic field exposure can occurred from the permanently magnetized metal parts. During the NIOSH survey, several metal components were found magnetized with field strength levels as high as 300 to 400 gauss.

B. Medical

The mercury levels measured in this investigation indicate a potentially serious health hazard. Studies of groups of mercury-exposed workers have shown that urine mercury above approximately 100 µg Hg/L (which roughly corresponds to 100 µg Hg/g creatinine) can be associated with dysfunction in the kidney and/or nervous system.[20,21]

Despite this potential for adverse health effects, this investigation did not find a significant association between elevated urine mercury levels and signs or symptoms of neurologic or behavioral disease. There may be several explanations for this observation. First, studies of the health effects of mercury exposure have shown difficulties in defining which health effects may be expected at specific exposure levels; this may in part be due to the variability in the susceptibility of different individuals.[5] Second, some of the studies which have shown effects on the nervous system due to mercury exposure were conducted differently than the NIOSH health hazard evaluation. Whereas NIOSH looked for clinically apparent effects (effects which would be noticed by the worker or could be detected by a physician without specialized testing), these other studies employed very specialized procedures and sensitive testing equipment. Even in these studies, the relationship between mercury in urine and neurologic health effects was not definitive, but could only be identified as a general trend.[21]

In addition, the number of workers studied was relatively small. When an investigation is conducted with a small sample size, there is a possibility that the group of workers studied do not accurately represent the entire group of workers; this may account for some of the contradictory results of our investigation. Finally, it is possible that the workers most affected by mercury are less likely to stay in the workforce, so that over time the group of current employees in the plant is more likely to be free of symptoms. The workers who would have been most symptomatic, having left the plant for other jobs, would not be studied in an investigation of this type.

Therefore, despite the absence of a clear association between mercury exposure and health effects in workers at LCP, these workers may be at risk of more subtle manifestations of disease than this investigation was able to detect and should be protected by adherence to recommended occupational safety and health guidelines to minimize the probability of overexposure to mercury. Our analysis of the role of existing personal protective equipment and work practices in predicting urine mercury level indicated that none of these were significantly associated; the only significant predictor was job exposure. Although it is possible that workers did not accurately report their adherence to these practices, these results suggest that better environmental controls, protective equipment and work practices will be required to protect workers in high-exposure jobs.

VIII. RECOMMENDATIONS

1. All cell room workers should be provided with, and wear, either air-purifying respirators or powered air-purifying respirators equipped with mercury/chlorine cartridges. The mercury/chlorine cartridges must have end-of-service-life indicators. This program should be consistent with the NIOSH recommendations and the requirements set forth in the OSHA Safety and Health Standards.[22,23] Respiratory protection should be used until industrial hygiene data document a reduction in exposures below the respective exposure limits.

2. All workers entering the acid burners area should first don their respirators equipped with acid gas cartridges. The present procedure of donning the respirators after the detection of the acrid acid vapors and mists does not protect workers in this area from the acute exposure hazard associated with hydrochloric acid. When not being worn by the worker, the respirators and cartridges should be stored in sealable plastic bags to prevent contamination.

3. Spills and leaks of mercury should be promptly cleaned up either mechanically or chemically. This includes all visible beads of mercury. No blowing or dry sweeping should be permitted. When vacuum cleaners are used, they should be equipped with mercury vapor absorbing filters to prevent dispersal of mercury vapors into workplace air. Efforts should be made to reduce the number of spills and leaks.

4. The ceiling fans should be operated at all times to increase the amount of air circulation in the cell rooms.

5. Waste mercury or materials contaminated with mercury should be kept in vaporproof containers, under water, or in chemically treated solutions, pending removal for disposal or processing for reuse.

6. Decontamination procedures should be initiated in the first aid room to reduce the levels of mercury in this room. Area air sampling for mercury should be performed in other non-work areas to determine the extent of the mercury contamination. If other areas are identified as being contaminated, then clean-up procedures should be performed to reduce the mercury levels.

7. Adequate shower facilities with hot and cold water should be available for use and used by the workers before they change into their street clothes. Workers who leave the cell room to visit other areas of the plant where mercury is not used, should first shower and change into their street clothes or uncontaminated work clothes.

8. Work and street clothing should not be stored in the same locker.

9. Before removal, work clothing should be vacuumed with a dedicated mercury vacuum.

10. Mercury-contaminated clothing should be stored in vaporproof containers pending laundering.

11. No smoking, eating, or drinking should be allowed in the cell rooms (including the break rooms) or other mercury work areas. These activities should be restricted to designated areas away from contaminants. Workers should wash their hands before eating, drinking, or smoking.

12. A local exhaust ventilation system which adequately removes mercury vapors should be installed in the mercury pump repair area of the maintenance shop. In the interim, workers in this area should be provided with, and wear, mercury vapor respirators.

13. LCP should purchase appropriate magnetic field monitoring instruments for use at the various areas within all their facilities having magnetic fields.

14. The company should investigate the need and usefulness of purchasing non-magnetized wrenches and tools. Several of the workers were aware of such tools and further study is warranted. In addition, caution signs should be posted stating the presence of magnetic fields and of the need to remove magnetic field sensitive items, such as watches, rings, etc.

15. Personnel must be aware that magnetic fields exist from moving current as well as in metal parts that have become permanently magnetized over time. Exposure can occur from both of these sources.

16. All workers should be educated concerning the potential reproductive health hazards associated with mercury exposure as discussed on page 9 on this report. In addition, LCP should be sensitive to employee requests for reassignment to a no-mercury-exposure job based on reproductive health concerns.

17. The biological monitoring program used at LCP during the time of the NIOSH visits requires modification to accurately achieve its goal of worker protection. As originally conducted, the program required that a worker show a sustained urine mercury level in excess of 250 micrograms of mercury per liter (μg Hg/L) in a spot sample (not corrected for dilution) before he/she is removed from exposure. Spot urine samples must be corrected for dilution if they are to be representative of the worker's body burden of mercury. We recommend the use of the World Health Organization's biological threshold limit value of 50 μg Hg/g creatinine. If the

ACGIH proposed BEI of 35 μg Hg/g creatinine is adopted, then this should be used. Since creatinine is a protein excreted in the urine at a fairly constant amount per day regardless of urinary volume, this standard provides the necessary correction. The NIOSH investigators observed that when a worker's urine mercury level exceeded the limit, it was company policy to assume the cause was inadequate worker attention to work practices or hygiene; the worker was returned to the job after being retrained in these matters. Prior to being returned to an exposure area, we recommended that the worker be followed with periodic urine mercury measurements (for example, monthly) until at least two consecutive urine samples show that his/her urine mercury level has fallen below the acceptable limit. Repeatedly high levels of urine mercury in a number of workers might indicate a worksite or environmental problem beyond the issue of work practices. Finally, the NIOSH investigators recommended that workers not only be tested on a quarterly basis, but also be given a pre-placement urine test to establish a baseline level.

18. LCP should implement an exposure monitoring program for all workers potentially exposed to mercury, chlorine, and hydrochloric acid as well as any other hazardous substances that may be used in the workplace. This program should consist of sampling air from the worker's breathing zone to measure the worker's exposures to specific chemicals or substances. The purpose of this exposure monitoring is to determine whether exposures may exceed the applicable exposure limits. Exposure monitoring surveys should be performed on a annual basis, or whenever changes in work processes or conditions are likely to lead to a change in exposures. Though not all workers have to be monitored, sufficient samples should be collected to characterize the workers' exposures. Variations in work habits and production schedules, worker locations, and job functions should be considered when developing exposure monitoring protocols. All workers participating in the monitoring should be informed of the results, and the employer must maintain these records for a period of 30 years.

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10. OSHA Region IV

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
Results from Area Air Sampling for Hydrochloric Acid

LCP Chemicals & Plastics, Inc.
HETA 87-402
October 14, 1987

Sample Location	Sample Time	Sample Volume[1]	Concentration of HCl[2]
Sample Station, Acid Burners 2,4	0822-1334	49.2	2.0
Sample Station, Acid Burners 2,4	1335-1549	25.0	10.4
Sample Station, Acid Burners 1,3	0822-1235	51.9	0.9
Acid Burner 1	0815-1345	31.5	0.1
Acid Burner 3	0815-1338	49.5	1.0
Acid Burner 3	1549-1552	23.7	0.8
Acid Burner 4	0815-1245	53.7	0.3
Acid Burner 4	1349-1555	24.1	0.8
OSHA PEL			5.0[3]
NIOSH REL			5.0[3]
ACGIH TLV			5.0[3]

[1]-Units expressed in liters of air.
[2]-Units expressed in parts per million (ppm) of hydrochloric acid.
[3]-Evaluation criterion is a ceiling limit that should not be exceeded during the workshift

Table 2
Results from Area Air Sampling for Chlorine

LCP Chemicals & Plastics, Inc.
HETA 87-402
October 14, 1987

Sample Location	Sample Time	Sample Volume[1]	Concentration of Chlorine[2]
Cell Room 1, Cell #28	0851-1441	350	0.02
Cell Room 1, Cell #35	0852-1441	349	0.01
Cell Room 1, Cell #11	0852-1441	349	0.01
Cell Room 2, Cell #75	0854-1336	282	0.01
Cell Room 2, Cell #90	0855-1444	349	0.04
Cell Room 2, Cell #82	0856-1326	270	0.06
Saturation Pump #R322	0911-1447	336	0.57
Average Chlorine Level (n=7)			0.10
OSHA PEL			0.5
NIOSH REL			0.5
ACGIH TLV			0.5

[1]-Units expressed in liters of air.
[2]-Units expressed in parts per million (ppm) of chlorine.

Table 3
Results from Area Air Sampling for Chlorine-First Shift Air Sampling

LCP Chemicals & Plastics, Inc.
HETA 87-402
April 26-27, 1988

Sample Location	Sample Time	Sample Volume[1]	Concentration of Chlorine[2]
Cell Room 1, Cell #49	0759-1305	306	0.66
Cell Room 1, Cell #22	0759-1306	277	0.26
Cell Room 1, Cell #3	0759-1310	311	0.11
Cell Room 1, Cell #10	0759-1308	309	0.12
Cell Room 1, Cell #14	0759-1307	308	0.09
Cell Room 1, Cell #43	0759-1307	308	0.17
Cell Room 1, Cell #29	0759-1310	311	0.08
Cell Room 1, Work Station	0759-1305	306	0.30
Cell Room 1, Cell #38	0759-1307	308	0.13
Cell Room 1, Cell #54	0819-1322	303	0.20
Cell Room 2, Cell #91	0819-1324	275	0.21
Cell Room 2, Cell #61	0819-1328	303	1.10
Cell Room 2, Work Station	0819-1322	303	0.21
Cell Room 2, Cell #66	0819-1324	283	0.53
Cell Room 2, Cell #86	0819-1321	272	0.19
Cell Room 2, Cell #73	0819-1323	304	0.15
Cell Room 2, Cell #80	0819-1326	307	0.20
Average First Shift Chlorine Level (n=17)			0.28
OSHA PEL			0.5
NIOSH REL			0.5
ACGIH TLV			0.5

[1]-Units expressed in liters of air.
[2]-Units expressed in parts per million (ppm) of chlorine.

Table 4
Results from Area Air Sampling for Chlorine-Second Shift Air Sampling

LCP Chemicals & Plastics, Inc.
HETA 87-402
April 26-27, 1988

Sample Location	Sample Time	Sample Volume[1]	Concentration of Chlorine[2]
Cell Room 2, Cell #73	1530-1913	223	0.20
Cell Room 2, Cell #98	1530-1910	220	0.36
Cell Room 2, Cell #92	1530-1911	221	0.43
Cell Room 2, Cell #67	1530-1911	221	0.32
Cell Room 2, Cell #81	1530-1912	222	1.40
Cell Room 2, Cell #64	1530-1912	222	0.57
Cell Room 2, Center Aisle	1535-1910	215	0.46
Cell Room 1, Cell #5	1520-1920	240	1.38
Cell Room 1, Cell #24	1520-1915	235	0.77
Cell Room 1, Cell #3	1520-1918	238	1.13
Cell Room 1, Cell #19	1520-1914	234	0.77
Cell Room 1, Center Aisle	1520-1914	234	1.25
Cell Room 1, Cell #44	1520-1915	235	1.59
Cell Room 1, Cell #49	1520-1916	236	0.96
Cell Room 1, Cell #12	1520-1917	237	0.94
Cell Room 1, Cell #30	1520-1920	240	0.75
Average Second Shift Chlorine Level (n=16)			0.83
OSHA PEL			0.5
NIOSH REL			0.5
ACGIH TLV			0.5

[1]-Units expressed in liters of air.
[2]-Units expressed in parts per million (ppm) of chlorine.

Table 5
Results from Personal Breathing Zone Air Sampling for Mercury
Passive Air Sampling Method

LCP Chemicals & Plastics, Inc.
HETA 87-402
October 14, 1987

Job Title	Job Location	Sampling Time[1]	Concentration of Mercury[2]
Operator	Cell Room 1	6.9	76
Operator	Cell Room 1	7.0	62
Assembly	Cell room 1	7.0	197
Assembly	Cell Room 1	7.0	161
Assembly	Cell Room 1	7.0	125
Assembly	Cell Room 1	6.7	72
Operator	Cell Room 2	6.7	90
Operator	Cell Room 2	6.9	78
Assembly	Cell Room 2	6.9	150
Assembly	Cell Room 2	6.9	132
Assembly	Cell Room 2	6.8	192
Assembly	Cell Room 2	6.8	220
Assembly	Cell Room 2	6.8	105
Mercury Handler	Cell Rooms 1,2	6.4	197
Mercury Handler	Cell Rooms 1,2	6.4	124
Mercury Handler	Cell Rooms 1,2	6.4	135
Average Mercury Exposure in Operators (n=4)			77
Average Mercury Exposure in Mercury Handlers (n=3)			152
Average Mercury Exposure in Assemblers (n=9)			150
Average Mercury Exposure Level (n=16)			132
OSHA PEL			50
NIOSH REL			50
ACGIH TLV			50

[1]-Units expressed in hours (hrs).
[2]-Units expressed in micrograms of Hg per cubic meter of air (ug/m^3)

Table 6
Result from Personal Breathing Zone Air Sampling for Mercury
Active Air Sampling Method-First Shift

LCP Chemicals & Plastics, Inc.
HETA 87-402
April 26, 1988

Job Title	Job Location	Sample Time	Sample Volume[1]	Concentration of Mercury[2]
Assembly	Cell Room 1	0717-1513	45.8	63.4
Assembly	Cell Room 1	0718-1512	44.7	44.7
Assembly	Cell Room 1	0715-1514	45.7	32.8
Assembly	Cell Room 1	0722-1510	38.2	31.4
Assembly	Cell Room 2	0715-1513	38.1	44.6
Assembly	Cell Room 2	0715-1512	44.2	29.4
Assembly	Cell Room 2	0715-1515	47.0	31.9
Assembly	Cell Room 2	0712-1512	41.9	38.2
Assembly	Cell Room 1	0723-1514	44.6	29.2
Assembly	Cell Room 2	0719-1510	43.8	34.3
Assembly	Cell Room 2	0719-1510	36.6	98.4
Assembly	Cell Room 1	0730-1512	43.0	65.1
Hg Handler	Cell Room 1,2	0711-1455	45.4	52.9
Hg Handler	Cell Room 1,2	0711-1510	44.4	60.8
Foreman	Cell Room 1	0730-1512	43.0	65.1
Foreman	Cell Room 2	0726-1523	44.7	24.6
Operator	Cell Room 1	0701-1453	45.9	37.0
Operator	Cell Room 1	0702-1450	45.7	37.2
Operator	Cell Room 1	0706-1500	45.5	22.0
Operator	Cell Room 2	0707-1515	48.4	22.7
Operator	Cell Room 2	0705-1513	47.7	27.3
Operator	Cell Room 1	1055-1450	23.3	39.9
Average Mercury Exposure in Operators (n=6)				31.0
Average Mercury Exposure in Mercury Handlers (n=2)				56.9
Average Mercury Exposure in Assemblers (n=12)				45.3
Average Mercury Exposure Level in Foremen (n=2)4				44.9
Average Mercury Exposure Level (n=22)				42.4
OSHA PEL				50
NIOSH REL				50
ACGIH TLV				50

[1]-Units expressed in liters of air.
[2]-Units expressed in micrograms of mercury per cubic meter of air.

Table 7
Result from Personal Breathing Zone Air Sampling for Mercury
Active Air Sampling Method-Second Shift

LCP Chemicals & Plastics, Inc.
HETA 87-402
April 27, 1988

Job Title	Job Location	Sample Time	Sample Volume[1]	Concentration of Mercury[2]
Operator	Cell Room 1	1517-2255	45.2	13.5
Operator	Cell Room 1	1518-2255	44.8	26.7
Operator	Cell Room 2	1519-2255	44.7	35.8
Operator	Cell Room 2	1520-2242	43.5	20.0
Operator	Cell Room 2	1610-2242	36.9	29.8
Operator	Cell Room 1	1610-2258	39.7	47.9
Foreman	Cell Room 2	1518-2255	42.3	26.0
Average Mercury Exposure in Operators (n=6)				29.0
Average Mercury Exposure Level (n=7)				28.5
OSHA PEL				50
NIOSH REL				50
ACGIH TLV				50

[1]-Units expressed in liters of air.
[2]-Units expressed in micrograms of mercury per cubic meter of air.

Table 8
Area Air Sampling for Mercury

LCP Chemicals & Plastics, Inc.
HETA 87-402
April 26-27, 1988

Sample Location/Cell Room No.	Sample Time	Sample Volume[1]	Concentration of Mercury[2]
Assembly Maintenance Area/1	0756-1456	39.9	20.6
Assembly Maintenance Area/1	1544-2055	42.8	17.1
Assembly Maintenance Area/2	0801-1500	37.8	34.4
Assembly Maintenance Area/2	1532-2055	42.5	5.9
Break Room/1	0753-1454	40.3	37.2
Break Room/1	1544-2055	42.6	20.9
Break Room/2	0802-1500	36.9	37.9
Restroom/1	1544-2055	41.1	13.9
Restroom/2	1531-2042	41.9	7.6
Laundry Room	0808-1530	40.1	14.0
Locker Room	0809-1520	41.0	21.2
Center Aisle/1	0755-1453	38.6	19.2
Center Aisle/1	1524-2055	24.5	25.3
Center Aisle/2	0803-1500	39.9	16.5
Center Aisle/2	1520-2255	45.8	59.0
First Aid Room	1508-2055	46.5	21.5
Maintenance/Hg Pump Repair	1554-2055	39.8	40.2
West End Under Cell #2	1534-2042	39.5	101.3
East End Under Cell #2	1539-2042	40.3	15.9
South End Under Cell #1	1545-2055	42.7	12.4
OSHA PEL			50
NIOSH REL			50
ACGIH TLV			50

[1]-Units expressed in liters of air.
[2]-Units expressed in micrograms of mercury per cubic meter of air.

Table 9
Summary of Urine Mercury Levels

LCP Chemicals & Plastics, Inc.
HETA 87-402
April 26-27, 1988

Job Title	N[1]	Mean Urine Mercury[2]	Range[2]
All cell room jobs	24	281	22-689
Cell assembly	12	311	152-438
Cell operators	10	258	22-689
Cell foremen	2	215	141-288
Maintenance & mechanics	12	26	5-38
Mercury handlers	2	48	39-57
Others	19	38	2-159
Unclassified	1	9	
ALL WORKERS COMBINED	58	136	2-689

WHO Study Group Guideline for Mercury in Urine	50
ACGIH Proposed BEI for Mercury in Urine	35

[1]-N=number of workers in this category
[2]-Urine mercury level in micrograms mercury per gram of creatinine

Table 10
Summary of Urine Mercury Levels and Neurologic Test Results

LCP Chemicals and Plastics, Inc.
HETA 87-402
April 26-27, 1988

Neurologic test	Normal N[1,2]	Normal Mean Urine Mercury[3]	Abnormal N[1,2]	Abnormal Mean Urine Mercury[3]	Significance of difference
Extraocular movements	56	135	0	---	---
Lid lag	55	137	1	30	p=0.50
Nystagmus	52	133	3	79	p=0.56
Resting tremor	55	136	0	---	---
Static tremor	48	149	8	55	p=0.005
Intention tremor	50	141	5	91	p=0.05
Finger-to nose	51	128	4	254	p=0.07
Diadocho-kinesis	47	144	8	93	p=0.36
Heel-to-toe walking	56	135	0	---	---
Romberg	55	137	1	49	p=0.58

[1]-N=Number of workers in this category.
[2]-Total workers participating in each test vary between 55 and 56 because some test results were not recorded for two workers.
[3]-Urine mercury level in micrograms mercury per gram of creatinine.

Table 11
Summary of Urine Mercury Levels and Deep Tendon Reflexes

LCP Chemicals and Plastics, Inc.
HETA 87-402
April 26-27, 1988

Neurologic test	Normal		Abnormal		Significance of difference
	N[1]	Mean Urine Mercury[2]	N[1]	Mean Urine Mercury[2]	
Right Biceps	30	111	26	163	p=0.22
Left Biceps	30	111	26	163	p=0.22
Right Triceps	23	105	33	156	p=0.25
Left Triceps	22	109	34	152	p=0.32
Right Patella	43	125	13	171	p=0.38
Left Patella	42	125	14	164	p=0.44
Right Ankle	48	130	8	165	p=0.60
Left Ankle	48	130	8	165	p=0.60

[1]-N=Number of workers in this category.
[2]-Urine mercury level in micrograms mercury per gram of creatinine.