HETA 98-0217-2768
Puerto Rico Aqueduct and Sewer Authority
Sergio Cuevas Bustamante Filtration Plant
Frujillo Alto, Puerto Rico

Lynda M. Ewers, Ph.D.
Ali Lopez, M.D.
Carlos Rodriguez, M.D.

PREFACE

The Hazard Evaluations and Technical Assistance Branch of the National Institute for Occupational Safety and Health (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 or 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.

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Lynda M. Ewers, Ali Lopez, and Carlos Rodriguez of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Teresa Seitz. Analytical support was provided by DataChem Laboratories. Desktop publishing was performed by Denise Ratliff. Review and preparation for printing was performed by Penny Arthur.

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Highlights of the NIOSH Health Hazard Evaluation

Evaluation of Hydrated Lime Exposures of Workers at a Potable Water Filtration Plant

NIOSH investigators responded to a confidential employee request for a Health Hazard Evaluation (HHE) at the Sergio Cuevas Bustamante Filtration Plant. There was concern about respiratory problems and dermatitis, possibly caused by exposures to hydrated lime, chlorine gas, or coagulants.

What NIOSH Did

- We talked with workers to see if health problems might be related to work conditions.
- We tested the air for chlorine gas.
- We tested the air for hydrated lime when it was being pumped to the top of the storage silo.
- We walked through the plant to observe work tasks, work practices, and housekeeping.

What NIOSH Found

- Some workers have respiratory problems which could worsen by exposure to hydrated lime dust.
- Hydrated lime is escaping from the silo and contaminating work areas.
- No chlorine gas was found in the work areas.
- Workers did not wear respirators and eye protection.
- Workers were not given clear standard operating procedures needed for their safety.

What the Bustamante Filtration Plant Managers Can Do

- Evaluate the design of the hydrated lime silo to see if it can be made easier and safer to maintain.
- Establish a safety and health committee with both management and worker members to decide the best methods to improve safety.
- Implement a respirator program.
- Write and follow standard operating procedures for hazardous tasks.
- Post signs around the plant so that workers understand what type of personal protective equipment is needed in each area.
- Investigate accidents promptly and encourage workers to quickly report incidents and accidents.

What the Bustamante Filtration Plant Employees Can Do

- Always wear eye protection and other protective clothing when exposed to hydrated lime.
- Report any exposures to hydrated lime, chlorine, or other chemicals to the safety and health committee or your supervisor.
- Follow standard operating procedures when performing potentially dangerous tasks.

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National Institute for Occupational Safety and Health
NIOSH

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SUMMARY

On May 6, 1998, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a Health Hazard Evaluation (HHE) at the Sergio Cuevas Bustamante Filtration Plant of the Puerto Rico Aqueduct and Sewer Authority. The requesters expressed concern regarding respiratory problems and dermatitis possibly associated with exposures to hydrated lime [calcium hydroxide, $Ca(OH)_2$], chlorine gas [Cl_2], and two coagulants [GC 850 (basic aluminum chloride solution) and PRP 4440 (polydimethydiallylammonium chloride)]. A site visit was conducted at this potable water filtration plant on June 29-30, 1998.

Of the 25 people employed at the filtration plant, 19 (76%) worked the morning shift (6 a.m. to 2 p.m.), when most of the activities at the filtration plant were performed. On the day of the site visit, 17 employees were present and all were interviewed. Two of the interviewed workers reported that they were diagnosed by physicians as having asthma, which had developed since working at this plant. Both workers reported noticeable improvements of this health condition during vacations, sick leave, or lay-offs. Five of the workers (including the two asthmatics) reported at least two respiratory symptoms in the ten days preceding the interview. These symptoms included difficulty breathing, phlegm production, chest tightness, wheezing, and shortness of breath. All symptomatic workers reported that they believed their symptoms were related to long-term exposure to hydrated lime and chlorine gas. Other reported health problems included sinusitis, itchy eyes, skin rash, and dermatitis.

Area air sampling for hydrated lime, chlorine, and particulates was conducted at locations and times of anticipated elevated exposures. Personal breathing zone (PBZ) air sampling for hydrated lime also was performed; however, the method used to analyze the hydrated lime failed. A count of particles in air during hydrated lime loading operations, a procedure reported by workers to often result in elevated dust levels, revealed only moderate losses of hydrated lime during loading when compared to the period after loading. No detectable levels of chlorine were measured in the area where chlorine cylinders were stored or in the room where chlorine was added to the water supply. The two coagulants of concern were confined to an area where little human exposure should occur, so monitoring was not conducted.

Management and employees reported that there had been problems associated with the handling of hydrated lime in the past. A crack, still visible but repaired by the time of the NIOSH site visit, had developed in the side of a silo which contained about 130,000 pounds of hydrated lime, allowing hydrated lime to be released into the workplace. The conveyor feeding hydrated lime into the water supply was designed to have barriers around it but they had been removed and hydrated lime was observed on surfaces throughout the room. Workers reported that hydrated lime periodically escaped into the environment from the top of the silo during loading, despite a filtration system to prevent its escape. The connection between the supply truck and the pipes carrying the hydrated lime to the top of the silo was difficult to seal properly and reportedly hydrated lime was spilled. On the day preceding the NIOSH site visit, a worker received a dose of hydrated lime in the face during a maintenance task at the silo. Several other safety concerns were identified at the plant, including absence of appropriate guarding of roof openings and lack of a complete confined space entry program, which indicate that more rigorous administrative controls should be implemented.

Some of the health effects reported by employees are consistent with hydrated lime or chlorine exposures, but more likely were due to the former given the low chlorine exposures. Air concentrations for chlorine were below occupational exposure limits during the survey. According to workers and management, most of the perceived high exposure events were episodic and occurred primarily during periodic maintenance tasks, most of which were not performed during the NIOSH site visit. Several safety hazards were identified. Recommendations were made to improve the design of the silo system, institute a respiratory protection program, evaluate the administrative controls, continue efforts to improve health and safety education and training, and eliminate safety hazards.

Keywords: SIC 4941 (Water supply) water treatment, hydrated lime (calcium hydroxide), chlorine gas, safety

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INTRODUCTION

On May 6, 1998, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a Health Hazard Evaluation (HHE) at the Sergio Cuevas Bustamante Filtration Plant of the Puerto Rico Aqueduct and Sewer Authority. The requesters expressed concern regarding possible health effects, especially respiratory problems and dermatitis, which they believed were associated with exposures to hydrated lime [calcium hydroxide, $Ca(OH)_2$], chlorine gas [Cl_2], and two coagulants [GC 850 (basic aluminum chloride solution) and PRP 4440 (polydimethydiallylammonium chloride)].

A site visit was conducted at this potable water filtration plant on June 29-30, 1998. An opening conference was held with management and employee representatives. A NIOSH medical officer interviewed workers to determine if symptoms could be related to occupational exposures, particularly to chlorine or hydrated lime. Two NIOSH industrial hygienists monitored both personal breathing zone and area air for hydrated lime, particulates, and chlorine. The purpose of this report is to present the results of the investigation and recommendations for reducing chemical exposures and improving safety procedures.

BACKGROUND

The Sergio Cuevas Bustamante Filtration Plant is an approximately forty-year old facility located near San Juan. The basic water treatment procedures in use are:

- pre-chlorination (using chlorine gas),
- aeration,
- addition of hydrated lime to increase effective-ness of coagulants,
- addition of primary and secondary coagulants to aid in particulate removal,
- settling of particulates in flocculation basins,
- filtration,
- activated carbon treatment (only under low water level conditions), and
- post-chlorination (using chlorine gas).

According to the facility management, this plant is one of the largest in Puerto Rico, and it is operating at four times the capacity for which it was built. At the time of the NIOSH site visit, several projects had been completed or were in progress to upgrade and modernize the plant, a process that has been underway for several years. For example, water treatment procedures were changed in 1994, when the types of coagulation compounds were changed. A new analytical laboratory was completed in 1998. Ongoing construction projects included: increasing the number of hydrated lime storage silos (from one to three), installation of new coagulant holding tanks, and replacement of some safety devices (e.g., eyewash stations). Plant management was also initiating new employee training programs, especially regarding risk communication and confined space entry requirements.

Approximately 25 permanent workers were employed at the plant. Most tasks were performed during the day shift (6 a.m. to 2 p.m.), but three workers were employed on each of the other two shifts. In addition, about 20 contract workers were active in construction work.

Employees performed a wide diversity of tasks, many of which were intermittent. Eight flocculation basins, where water movement was slowed to permit sludge settling, were drained and cleaned on a schedule of about two basins per week. The 2000-pound chlorine gas tanks needed to be changed about every 36 hours. Hydrated lime was pumped from a pressurized tanker truck into the storage silo every other day. Filters in the top of the hydrated lime silo were changed every three months. It was not possible to observe all tasks during the site visit. Instead, one potentially problematic task, identified from telephone interviews with employees prior to the visit, formed the focus of the investigation: filling of a silo with hydrated lime. Secondary concerns were chlorine and coagulant exposures.

Processes

Hydrated Lime Treatment

The silo, which stored about 130,000 pounds of hydrated lime, was situated in the center of the water treatment plant. It extended from about one story above the roof of the facility, through two floors of the plant, to the ground floor. In order to fill this silo, a tanker truck was backed up to a newly-installed outdoor delivery system, which snaked up the outside of the building to the top of the structure. Hydrated lime was pumped from the truck under pressure, a process requiring about two hours. Plant employees were not directly involved in the filling process but were present nearby; the hydrated lime supplier performed this task.

A revolving belt system continuously fed hydrated lime from the bottom of the silo through a hole in the floor into the water supply flowing beneath the plant. This system was located in a room which could only be entered from the outside of the facility, so there was limited possibility for the hydrated lime to directly contaminate the plant. A considerable amount of hydrated lime dust coated the surfaces of this room. A metal barrier around this revolving belt, which would restrict the amount of hydrated lime which could escape into the room, had been removed. According to management, employees cleaned this room once per week and checked the feed mechanism periodically throughout the day, a task that required about 10 minutes. Air-purifying, particulate-filtering half-mask respirators (NIOSH-approved, Dräger Picco 20) were available for use in this room, as well as Tyvek® suits, goggles, and heavy rubber gloves.

Chlorine Cylinder Replacement

Although chlorine cylinder replacement was not observed by the NIOSH team, management reported that about 10 minutes were required to change one of the 2000-pound chlorine cylinders. Cylinder replacement was the most likely time for accidental leaks of chlorine gas, and several policies for worker and community protection were included in an operations manual for the plant.[1] Cylinder changes were restricted to the first shift, so that leaks would be unlikely to occur during periods of low staffing. An ammonia/water solution was released into the air during cylinder replacement to detect chlorine leaks; a solid white precipitate (ammonium chloride) forms if chlorine is present. Workers reported that they carried, but did not wear, full-facepiece, chin-style gas masks with canisters for chlorine gas and dusts (NIOSH-approved, Wilson™) when changing cylinders. Advance™ continuous monitoring gas detectors (Capital Controls) were located in both the chlorine cylinder area and the area where chlorine was metered into the water system. The detectors were maintained by an outside contractor, who was responsible for the gas detectors' calibration. In a safety cabinet located in a central area of the facility, a self-contained breathing apparatus (SCBA) (NIOSH-approved, Scott® Air Paks®) was available, although no protective suits, gloves, boots, or other protective equipment was located there. The management had plans to train workers in proper respirator use but, in case of an emergency, primary reliance was on local public services outside the plant.

Coagulant Addition

The purpose of the coagulant addition and subsequent sedimentation was to remove entrapped bacteria, viruses, suspended particles and colloidal matter. The addition of two liquid coagulants to the water was managed automatically. Primary coagulant, GC 850 (basic aluminum chloride solution), flowed from hoses into the agitated water within a flume. Addition of a secondary coagulant, the polymer PRP 4440 (polydimethyldiallylammonium chloride), occurred more slowly within eight sedimentation basins. According to management, employees enter the basins to remove accumulated sludge (a process not observed by NIOSH researchers). Sludge was shipped to another plant for disposal.

METHODS

Medical

The medical evaluation consisted of interviews and an orally administered questionnaire. Questions were formulated to elicit information about respiratory symptoms, as well as potential skin, eye, and sinus problems. Interviews and oral questionnaires were conducted in Spanish, and all day-shift employees were invited to participate.

Environmental

Hydrated Lime

Area particle counts were measured as a surrogate for the hydrated lime exposure during the silo filling process, when maximum routine hydrated lime exposures were expected. The Met One Model 227 Hand-Held Particle Counter (Grants Pass, Oregon) counted particles in two ranges: 0.3 microns (µ) and larger, and 5.0 µ and larger; the instrument has a 15-second cycle, which includes 10 seconds of counting followed by a 5-second rest. The Met One was positioned over the connection between the supply hose from the truck and the pipe leading up the side of the building to the silo, a location where maximal exposures were anticipated. The Met One was run at the beginning and end of the hydrated lime pumping operation, and for approximately 30 minutes after the truck had departed. Thus, comparisons could be made with background periods when no hydrated lime was being pumped.

NIOSH Method 7401 for alkaline dusts was selected as the most appropriate method to estimate personal and area time-weighted average (TWA) exposures to hydrated lime.[2] Four, full-shift, personal breathing-zone (PBZ) air samples were collected from the plant operator, assistant operator, shift supervisor, and mechanic; two area samples were collected from the hydrated lime room and the top of the silo.

Chlorine

Colorimetric detector tubes (Dräger, Inc.) for chlorine gas [measuring range of 0.3 - 5 parts per million (ppm)] with associated bellows pump were used for short-term measurements in both the chlorine tank area and in the two rooms where chlorine was metered into the water supply. The detector tubes have an accuracy of +/- 25-30%.

Coagulants

The two coagulants in use at the Bustmante plant, GC 850 and PRP 4440, were in solution and, under normal circumstances, there appeared to be little chance for worker exposure via the inhalation route. Consequently, air sampling was not performed for these compounds.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours 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 even though 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 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 increases 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 Recommended Exposure Limits (RELs),[3] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[4] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[5] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criteria.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm.[6] Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PEL's and STEL's. An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

A 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 (C) values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Hydrated Lime

Hydrated lime can cause caustic irritation of all exposed body surfaces and the respiratory tract.[7] Inhalation of hydrated lime is irritating to the nose and can be damaging to the upper respiratory tract. The irritant and corrosive properties of hydrated lime are primarily a result of alkalinity and heat-generation when the hydrated lime comes in contact with moisture. Skin exposure can produce chronic dermatitis and corrosive chemical burns. Because hydrated lime slowly penetrates the skin, the degree of damage is directly related to the amount and duration of exposure. In the respiratory system, hydrated lime exposure can produce coughing, sneezing, and inflammation of the nose and throat, bronchitis, and pneumonia. Chronic inhalation exposure can cause coughing, fluid in lungs, and difficult breathing. Ocular exposure can produce spasmodic blinking, and tears. If calcium hydroxide particles adhere to the eyeball and the conjunctival sac, ulceration, and corrosive burns may result. We could find no literature specifically relating occupational asthma with acute or long term exposure to hydrated lime. However, it is thought that non-sensitizing respiratory tract irritants, such as hydrated lime, may be associated with the development and exacerbation of asthma.[8,9]

The NIOSH REL for hydrated lime is 5 mg/m^3 as a TWA for up to a 10-hour workday, based upon the possibility of caustic irritation of all exposed body surfaces and the respiratory tract. OSHA's PEL is 15 mg/m^3 for total hydrated lime dust and 5 mg/m^3 respirable hydrated lime dust. The ACGIH TLV-TWA is 5 mg/m^3 based on irritant effects.

Chlorine

Chlorine gas has a characteristic pungent and irritating odor that can be detected at concentrations of less than 0.5 ppm, although some workers chronically exposed to the gas become anosmic (loss of sense of smell). Health effects associated with chlorine exposure include severe eye, skin, and mucous membrane irritation. At low levels, acute chlorine gas inhalation may cause severe nose, throat, and upper respiratory tract irritation. Symptoms include itchy nose, dry throat, coughing, and difficulty breathing. At higher levels, chlorine exposure may result in shortness of breath, headache, chest pain, and vomiting. A severe exposure causes bronchitis, pulmonary edema, and usually death after a few deep breaths. Eye contact can produce severe eye irritation, burns, and possibly blindness. Skin contact with the liquified compressed gas may cause frostbite [10, 11] In some persons, an asthma-like syndrome, characterized by non-specific bronchial hyper-responsiveness, may develop after inhalation of even a single exposure to a high concentration of chlorine. This syndrome was described by Brooks et al. in 1985 and termed reactive airway dysfunction syndrome (RADS).[12] Symptoms of RADS include cough, shortness of breath, and wheezing.[8, 13, 14, 15]

Uncertainty exists about chronic effects of low-level chlorine exposure since this exposure has been studied in only a limited number of occupational cohorts. The largest published study of chronic chlorine inhalation is a survey of 332 workers in 25 chlorine-producing plants in the United States and Canada, together with an age-matched cohort of 382 control workers from the same plants not routinely exposed to chlorine.[16] Chlorine levels at various locations in each plant were measured throughout the study year. The TWA exposure to chorine gas ranged from 0.006 to 1.42 ppm, with a mean level of 0.15 ppm. In this study, workers with 10-14 years exposure to chlorine constituted the single largest group and contained the most workers with exposures greater than 0.5 ppm. At these levels, neither chest X-rays findings nor pulmonary function results showed any correlation with exposure.[17]

The NIOSH REL for chlorine gas is a 15-minute ceiling concentration of 0.5 ppm, based on its potential for producing severe eye, mucous membrane, and skin irritation; the level considered to be immediately dangerous to life and health (IDLH) is 10 ppm. The OSHA PEL is a ceiling concentration of 1 ppm. The ACGIH TLV - TWA is 0.5 ppm, and the STEL is 1 ppm. The ACGIH notes that chlorine is considered "not classifiable as a human carcinogen," meaning that it is an agent which causes concern that it could be carcinogenic for humans but cannot be assessed conclusively because of a lack of data.

Coagulants

The MSDS for GC850 indicated the possibility of skin and eye irritation and sensitization with repeated inhalation of mist. The MSDS for PRP 4440 lists skin, eye, gastrointestinal tract, and respiratory tract irritation. Both MSDSs reported no known chronic toxic effects. Reports in the scientific literature suggest that repeated skin contact with soluble salts of aluminum results in acid irritation.[18] The NIOSH REL for mists or dusts of soluble aluminum salts, which includes GC850, is a TWA of 2 mg/m^3 as aluminum for up to 10-hour workdays, based upon skin irritation effects. OSHA does not have regulatory standards for soluble aluminum salts. The ACGIH recommends a TLV - TWA of 2 mg/m^3 for soluble aluminum salts. No evaluation criteria exist for PRP 4440.

RESULTS

Medical

Of 25 (23 male, 2 female) employees, 17 (all male) were interviewed. They were classified as operators, mechanics, supervisors, lab technicians, and assistants. The reported mean number of years worked was 8 (range: 2 months to 20 years), and the mean number of hours worked per week was 38 (excluding one employee, who reported he worked an average of 60 hours per week). Of the 17 interviewed workers, 5 (29%) currently smoked cigarettes; they averaged 16 cigarettes per day. All said that they do not usually wear personal protective equipment to perform their daily activities. Five (29%) reported that they received one training session on how to use the self-contained breathing apparatus (SCBA) during emergency situations.

Two workers reported that they were diagnosed by physicians as having asthma. They stated that they never had asthma during childhood and started to develop this condition while working at the filtration plant. One of the asthmatic employees was hospitalized on several occasions due to exacerbation of his symptoms. Both workers reported noticeable improvement of their health while away from work, such as on vacation, sick leave, or lay-off. Five of the workers (including the two asthmatics) reported at least two respiratory symptoms in the 10 days preceding the interview. These symptoms included difficulty breathing, bringing up phlegm in the morning, chest tightness, and awakening at night with wheezing, whistling, and/or shortness of breath. All symptomatic workers reported that they believed their symptoms were related to long-term exposure to hydrated lime and chlorine.

Eleven workers (64%) reported sinus symptoms, such as stuffy nose or drainage at the back of the nose. Nine workers (52%) reported itchy and watery eyes with continuous redness, and four workers (24%) complained of skin rashes and/or dermatitis. They said that these symptoms were mostly present when hydrated lime was spilled and spread over the work area. This situation, according to the employees, normally occurred three or four times per month. All employees with symptoms (15 employees) noted that sinus, eye, and skin problems improved when they were away from work.

Environmental

Hydrated Lime

Unfortunately, field blanks indicated high and varied background levels, and thus the results were not valid. The results of real-time monitoring of particulates in air during and after hydrated lime loading into the storage silo are shown in Figure 1. The unloading began at 7:30 a.m. and finished at 9:10 a.m.; hose detachment was completed by 9:15 a.m. and the truck left the site at 9:24 a.m. Air monitoring after 9:24 a.m. is indicative of background levels. Although there is much variability in the data, the pattern shown in Figure 1 indicates only moderate hydrated lime losses, primarily during the first fifteen minutes after pumping had begun. Since this process was identified by workers as having problems with hydrated lime releases in the past, such releases may be related to occasions when the truck hose was not adequately connected to the pipe, a task which required considerable effort.

Chlorine

No chlorine was detected on Dräger tube samples collected in the chlorine cylinder area or in the chlorine-water mixing area; the limit of detection was 0.3 ppm. No cylinder exchange (when accidental chlorine release is most likely) took place during the NIOSH visit.

DISCUSSION AND CONCLUSIONS

Health effects reported by workers are consistent with exposures to either hydrated lime and/or chlorine. It is possible that the exposures are primarily related to short-term exposures rather than typical daily operations. Two workers at the facility reported that their doctors diagnosed them with asthma. One of them reported mainly exposure to chlorine, and the other reported mainly exposure to hydrated lime. Both said their symptoms improved during weekends and holidays and worsened on return to work. This pattern suggests, but does not confirm, occupational asthma.[19] However, no objective diagnostic test for occupational asthma, such as spirometry, methacholine challenge, and/or pulmonary function testing at work, was reported to have been done in either case. Other health effects described by the interviewed workers, including eye, skin, and upper respiratory symptoms, may be related to the hydrated lime dust exposure. While chlorine gas might be a factor in respiratory irritation, our measurements and most worker interviews suggested that chlorine exposures were minimal. No recent incidents of high-level chlorine exposure were reported, and chlorine levels were not detectible in the cylinder storage and chlorine-water mixing areas on the day of the visit.

Several opportunities exist for reducing exposures to hydrated lime at this plant. Potential problems were observed relative to its storage:

(1) Accurate seating of the connector between the supply truck and line transmitting it to the top of the silo was difficult to accomplish. This is important to prevent hydrated lime from escaping when air pressure is applied to pump hydrated lime up approximately three stories. During the NIOSH visit, the truck operator had to hammer on the connection for several minutes before it was satisfactorily sealed and pumping could begin.

(2) Overfilling of the silo was possible. Workers stated that they tapped on the side of the silo to determine the hydrated lime level and then estimated when it was low enough to order another load. Inability to accurately judge the hydrated lime levels had resulted in releases in the past, according to workers.

(3) Filters were installed at the top of the silo and, if they became overloaded, the pressure exerted during the filling process contributed to hydrated lime dust escaping through any available opening in the silo. Some used and damaged filters were laying near the silo. Pressure had apparently collapsed their support skeleton, which would render them less effective than in their original state.

(4) The silo itself had developed a large crack, although it had been repaired by the time of the NIOSH visit. According to employees, hydrated lime was released into the building through this crack in the past.

(5) Feeding of the hydrated lime into the water supply allowed losses to the work environment. The mechanical belt used for the hydrated lime feed was designed to be enclosed within a metal shell, but this shell had been removed. The walls and floor of the room where this process occurred were covered with hydrated lime dust. The room was isolated from the inside of the plant, accessible only from an exterior door. One employee was observed within this area, and abandoned dust masks and respirators further attested to workers spending time there. According to management, these times were limited to about 10 minutes once a week for maintenance procedures. Although air sampling results for alkaline dusts were not valid, it was clear from our observations that employees could have significant exposure while working in the hydrated lime room, particularly if adequate respiratory protection and protective clothing was not worn.

The fact that an accident occurred during a maintenance activity on the day prior to our visit alerted NIOSH personnel to the possibility that improvements need to be made regarding safety procedures and safety culture at this plant. According to management, a worker had been replacing filters in the top of the hydrated lime silo when he was exposed to hydrated lime dust on his face. He had to climb down ladders three stories to access an eyewash station. A NIOSH investigator climbed to the roof, near where the hydrated lime exposure occurred, and observed a large (about 10 foot in diameter) opening in the roof extending to the floor below, apparently in preparation for installation of a new hydrated lime silo. No guarding or other protective devices surrounded the opening. OSHA regulations for construction require that openings have standard railings, which consist of a top rail, intermediate rail, toeboard, and posts.[20] An unguarded opening poses a serious fall hazard, especially if a worker becomes disorientated (as with hydrated lime in the eyes). The investigation of such accidents provides opportunities for organizations to evaluate and improve their safety program, but our discussions with management the day following the incident suggested that no such investigation occurred.

Further evidence of a lack of clarity regarding health and safety issues is reflected in the lack of signs cautioning employees of hazardous areas. For example, the removal of sludge from the flocculation basins, a process not performed the day of the site visit, places the employees at risk for exposures to high levels of the coagulants, microbes, parasites, and by-products of decomposition of organic matter (e.g., hydrogen sulfide gas). Direct contact with the sludge is inadvisable and largely unwarranted in most water treatment plants, where routine sludge removal is automated and employees only enter the sedimentation basins once or twice per year for complete cleaning.[21] In a tropical setting, it is possible that more sludge may be produced, necessitating more frequent manual cleaning. However, if entry is necessary, the flocculation basins meet OSHA's definition of a permit-required confined space in that the basins (1) are large enough and so configured that an employee can bodily enter and perform assigned work, (2) have limited or restricted means for entry or exit, (3) are not designed for continuous employee occupancy, and (4) contain or have a potential to contain a hazardous atmosphere or other recognized serious safety or health hazard.[22] No signs alerting employees to any confined space hazards were in evidence near the flocculation basins.

Contract construction workers were observed standing in water while performing work on an electric pump, a potential electrical hazard. The workers were not consistent in their use of PPE. Some wore rubber boots, others did not; some wore hard hats, others were bare-headed. No signs indicated whether or not hard hats or other PPE were required in areas of the plant where construction activities were occurring.

Often, the root cause of accidents is based in management and organizational factors not specific to one incident.[23] Four conditions have been identified for effective accident prevention: (1) evident commitment of top management, who must ensure systematic implementation of procedures; (2) investigator training; (3) informed management, supervisors, and workers; and (4) real improvements in safety conditions that will encourage future accident investigations.[23] During discussions, management said that they were considering setting up an employee-management health and safety committee. Such committees can be an important part of a solution for accident prevention. However, the ultimate responsibility for providing a safe workplace remains at the top management levels.

RECOMMENDATIONS

To address the acute and chronic health and safety concerns raised during the site visit at the Sergio Cuevas Bustamante Filtration Plant, the following recommendations are offered:

Engineering Controls

• Evaluate the design of the hydrated lime storage silos and the delivery process from the standpoint of worker safety and health. Determine if filters can be made more convenient to remove. Determine if the connection between the truck's hose and the delivery pipes could be made more convenient so that the operator would not have to spend several minutes hammering on the connection to be certain that it was tight. Replace the old silo as soon as possible.

• Enclose the mechanism to feed hydrated lime into the water, so that hydrated lime does not escape into the work environment.

• Evaluate the design of the sedimentation basins to determine if the removal of sludge can be automated and employee contact with the sludge and coagulants reduced. Extend the hose carrying the primary coagulant into the flume so that it is submerged, reducing the potential for worker exposure to the coagulant aerosol.

Administrative Controls

• Form a health and safety committee with representatives from top management as equal participants with employees to evaluate the safety climate at the plant and to determine the best methods to improve safety practices. Establish standard operating procedures for the more hazardous tasks (e.g. establish a buddy system). Implement the recommendations of this committee. Keep employees informed of the committee's activities.

• Investigate safety incidents or accidents thoroughly. An investigative report of an incident should include appropriate documentation: date, time, location, description of operations, description of accident, photographs, interviews of employees and witnesses, measurements, and other pertinent information.

• Establish which areas are permit-required confined space entries. Develop and implement appropriate written procedures for these policies consistent with OSHA standards.[24]

• Provide resources for improved housekeeping. Hydrated lime dust is a problem in some areas and should be removed by personnel wearing protective clothing and eye protection, by using techniques which do not result in the chemical being entrained in the air (i.e., do not sweep with a broom). More general cleanup is also needed; broken glass was observed on stairs. To facilitate housekeeping, consider adding water spigots in areas where frequent cleaning is required.

Personal Protective Equipment

• Establish a suitable respiratory protection program consistent with OSHA requirements.[25] Consider providing NIOSH-approved, helmeted, powered, air-purifying respirators (PAPRs) fitted with a high-efficiency particulate air (HEPA) filter for tasks that may have a risk of accidental exposure to hydrated lime. These loose-fitting respirators have an assigned fit factor of 25.[26] PAPRs are usually more comfortable to wear in warm weather because they provide an airstream, which has a cooling effect, and they have less breathing resistance than tight-fitting respirators. PAPRs can provide eye, face, and head protection as well as respiratory protection. Potential disadvantages include the need for frequent maintenance, the unacceptability to workers due to safety concerns, or the occurrence of episodic high exposures associated with particular tasks.

• Use eye protection or face protection for tasks where there is a potential for hydrated lime to be splashed or sprayed into the eyes.

• Provide portable eyewash devices, which can be transported to areas where maintenance or temporary tasks may result in eye contact with hydrated lime.

• Wear protective clothing and gloves when hydrated lime skin exposures are possible.[7] The following materials have been recommended for use against permeation by calcium hydroxide: natural rubber, nitrile rubber, and neoprene rubber.[27] Glove or clothing manufacturers can provide information on the expected times for penetration of hydrated lime through the materials. PPE should be changed if it is torn or becomes contaminated on the inside. If clothing contaminated with hydrated lime is to be washed, the person performing this task should be forewarned so steps to avoid skin contact can be taken.

Education

• Post signs throughout the plant alerting workers to where and what type of PPE is needed.

• Educate workers regarding respirator policies and how to properly use and care for respirators.

• Post signs indicating areas where permit-required confined-space entry restrictions apply.

• Instruct workers in proper first aid procedures to use if exposed to hydrated lime and chlorine.

• Encourage workers to report all possible work-related health problems. These problems should be investigated on an individual basis by the company and consulting health care providers. Because the causes of health effects and diseases may be difficult to assess, each person with possible work-related health problems should be fully evaluated by a physician, preferably one with expertise in occupational medicine. In some cases, workers may have to be reassigned to areas where exposure is minimized. Employees reassigned for work-related medical reasons should not lose seniority, wages, or other benefits to which they would be entitled had they not been reassigned.

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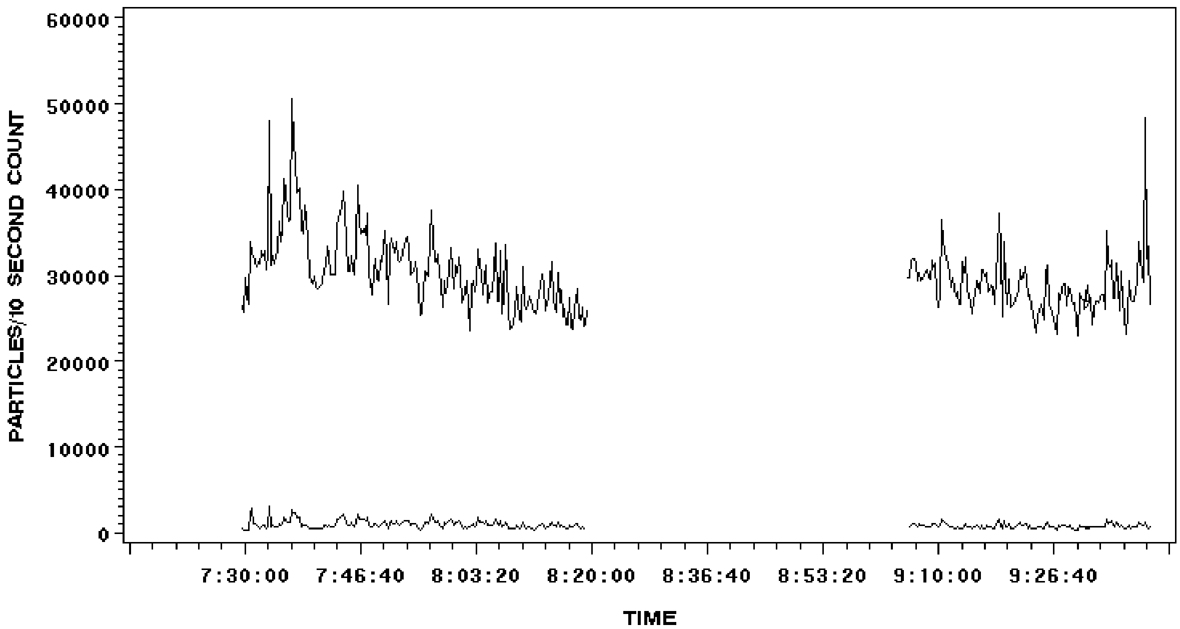

Figure 1. Particles in air during and after lime loading operations.
Sergio Cuevas Bustamante Filtration Plant
Puerto Rico Aqueduct and Sewer Authority

Note: Upper lines represent particles 0.3 microns (μ) and larger.
Lower lines represent particles 5.0 μ and larger.

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Call NIOSH at:
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or visit the NIOSH Web site at:
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