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Yankton Sioux Tribe–Marty Indian School
Marty, South Dakota

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Preface

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Acknowledgments and Availability of Report

This report was prepared by Ronald M. Hall and Yvonne Boudreau, of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Greg Kinnes and Tammy Wise. Analytical support was provided by Data Chem Laboratories, Salt Lake City, Utah. Desktop publishing was performed by Nichole Herbert and Ellen Blythe. Review and preparation for printing was performed by Penny Arthur.

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Health Hazard Evaluation Report HETA 98–0124–2743
Yankton Sioux Tribe–Marty Indian School
Marty, South Dakota
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SUMMARY

On February 25, 1998, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation (HHE) from management at the Yankton Sioux Tribe–Marty Indian School in Marty, South Dakota. The request concerned worker exposures to various contaminants (i.e., metals) contained in fly ash from burning used motor oil in two separate boilers. Worker exposures occur while cleaning the two boilers. Additional concerns included the possibility of lead contamination in the plumbing and machine shop areas.

An initial evaluation at the Marty Indian School was conducted on March 6, 1998. No evidence of lead contamination (based on qualitative wipe sampling) was found in the plumbing or machine shop areas. A follow-up on March 25–26, 1998, evaluated worker exposures during the boiler cleaning process and the possibility of cross-contamination of hazardous materials from the boiler area (during cleaning activities) into the plumbing or machine shop areas.

All area and personal breathing zone (PBZ) air samples collected during the boiler tube cleaning activities and samples collected in the general shop areas showed levels of lead, elements, and particulate that were well below established occupational exposure criteria. A 40–minute PBZ sample collected for lead (analyzed by NIOSH Method 7701) while the worker removed fly ash inside the boiler indicated a concentration of 1,340 micrograms per cubic meter ($\mu g/m^3$) with an 8–hour time-weighted average (TWA) of 112 $\mu g/m^3$. The 8–hour TWAs for lead, arsenic, cadmium, zinc oxide, and calcium sulfate (using NIOSH method 7300 for elements) were 190 $\mu g/m^3$, 5.3 $\mu g/m^3$, 1.5 $\mu g/m^3$, 1000 $\mu g/m^3$, and 2600 $\mu g/m^3$, respectively. The TWA results for cadmium, zinc oxide, and calcium sulfate were below applicable occupational evaluation criteria set by NIOSH, the Occupational Safety and Health Administration (OSHA), and the American Conference of Governmental Industrial Hygienists (ACGIH®). However, the lead TWAs exceed the NIOSH recommended exposure limit (REL) (<100 $\mu g/m^3$), OSHA permissible exposure limit (PEL) (50 $\mu g/m^3$), and the ACGIH Threshold Limit Value (TLV®) (50 $\mu g/m^3$). The arsenic TWA exceeded the NIOSH REL ceiling limit of 2 $\mu g/m^3$. Concentrations of other elements were below applicable occupational exposure criteria.

Bulk sample results indicate that the fly ash is contaminated with aluminum, arsenic, barium, lead, cadmium, calcium sulfate, chromium, copper, phosphorus compounds [possibly PO_4, P_2O_7, and PO_3 compounds, no elemental phosphorus was found], nickel, magnesium, manganese, molybdenum, and zinc. Bulk samples of pipe insulation obtained from utility tunnels at the school contained 40 – 50% chrysotile asbestos.

NIOSH representatives reviewed the results of blood lead testing conducted in March 1998 by representatives of the Agency for Toxic Substances and Disease Registry (ATSDR). This consisted of blood samples collected from

58 children and 41 adults at the Marty Indian School. None of the adults who worked in the shop or boiler area were tested.

The blood lead levels (BLLs) in the children ranged from <3 micrograms of lead per deciliter of blood (µg/dL), the detection limit, to 7.3 µg/dL, and in the adults ranged from <3 to 4.5 µg/dL. The geometric mean BLL in children was 1.8 µg/dL, and in the adults it was 1.6 µg/dL (using one-half the detection limit for non–detectable BLLs). None of the children's or adults' BLLs reported in the ATSDR study exceeded the Centers for Disease Control and Prevention (CDC) recommended action level of 10 µg/dL. However, blood lead samples were not collected from the employees who work in the shop or boiler area.

Air sampling results indicate overexposure to lead and arsenic when cleaning the inside of the boiler. Bulk sample results indicate that fly ash is contaminated with various elements. Engineering controls effectively limited exposures during the boiler tube cleaning activities. Pipe insulation in utility tunnels at the school contain 40 – 50% chrysotile asbestos. The boiler fits the criteria outlined in the toxicity parameter of a Class B confined space which warrants that the checklist for a Class B confined space be followed prior to entry. Recommendations for controlling worker exposures during the boiler cleaning process and for controlling asbestos-containing material at the school are provided in the report.

Keywords: SIC 8211(Boarding Schools), Boilers, Maintenance, Lead, Arsenic, Used motor oil, Confined Space

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INTRODUCTION

On February 25, 1998, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation (HHE) from management at the Yankton Sioux Tribe–Marty Indian School in Marty, South Dakota. The request concerned worker exposures to various contaminates (i.e., metals) contained in fly ash from burning used motor oil in the school's boilers. Worker exposures occur during cleaning of the boilers. Additional concerns regarded the possibility of lead contamination in the plumbing and machine shop areas adjacent to the boiler room.

An initial evaluation at the Marty Indian School was conducted on March 6, 1998, to become familiar with the boiler cleaning process and to investigate the possibility of lead contamination in the boiler room, plumbing shop, and machine shop areas. The findings from this site visit were reported in a previous letter.[1] No lead contamination was found in the plumbing or machine shop areas during the initial evaluation.

NIOSH investigators conducted a follow-up evaluation at the Marty Indian School on March 25–26, 1998, to evaluate worker exposures during the boiler cleaning process and to investigate the possibility of hazardous materials migrating from the boiler area (during cleaning activities) into the plumbing shop or machine shop areas.

BACKGROUND

The boilers at the school utilize used motor oil as a fuel source. Deposits from the used motor oil (fly ash) accumulates on the surfaces inside the boilers during the burning process. Approximately once a month, workers are required to clean the tubes on the boiler and enter the interior of the boiler to remove the fly ash. A rotary powered tube cleaner is used to remove fly ash from the boiler tubes. This tube cleaner is horizontally fed through a ventilation system which is attached to the 2½”- diameter tubes located on the boiler (see Figure 1). The tubes that run through the boiler are approximately 20 feet long. Fly ash accumulates inside the tubes and is removed by knives that are located on the end of the rotary cleaner. The fly ash is then transported out of the tubes by the ventilation system to a street sweeper located directly outside the boiler shop, and from the street sweeper into a smoke stack, where the fly ash either settles or is discharged to the environment (see Figure 2). After the worker has removed the fly ash from one tube, the tube cleaning apparatus (including the rotary tube cleaner and ventilation system) is moved to another tube on the boiler and the process is repeated until all the tubes have been cleaned.

After the boiler tubes have been cleaned, the worker must enter the interior of the boiler to remove additional fly ash with hand tools (i.e., brushes and scrapers). The dislodged fly ash is removed from the boiler interior by a movable ventilation duct (see Figure 3). The boiler has openings, approximately 16” in diameter, on each end. An additional ventilation duct is placed on the opposite end of the boiler to provide general ventilation in the interior.

METHODS

Industrial Hygiene Evaluation

On March 25–26, 1998, area air samples for lead and other elements were collected at the following four area locations (see Figure 4); (1) in the plumbing area located near the entrance to the boiler room (location A1), (2) in the machine shop near the entrance to the boiler room (location A2), (3) outside near the boiler room (location A3), and (4) outside the boiler room at the air intake (the air intake supplied air to an airline respirator [location A4]). These area samples were collected for approximately 280 minutes.

In addition to these four locations, area air samples for total dust, respirable dust (< 10 micrometers [µm] in diameter), elements, and lead were collected on each side of the boiler for approximately 280 minutes during the tube cleaning process, as well as directly outside the boiler for approximately 200 minutes during the boiler cleaning process. Air samples for total dust and respirable dust were collected for approximately 40 minutes inside the boiler during the cleaning process. Personal breathing zone (PBZ) air samples for lead and other elements were collected during both the tube cleaning (samples were collected for approximately 280 minutes) and interior boiler cleaning processes (samples were collected for approximately 40 minutes).

Lead

Qualitative lead wipe samples (i.e., to determine the presence of lead, not the amount) were collected using Lead✓Check™ swabs on various surfaces in the boiler room, plumbing area, and machine shop. The Lead✓Check™ swab turns pink or red if lead is present in the dust of the surfaces tested. Refer to Figure 4 for wipe sample locations.

Quantitative air samples for lead were collected and analyzed on site to provide immediate information on air lead concentrations. Samples were collected on 37–millimeter (mm) diameter (0.8–µm pore-size) mixed cellulose ester membrane filters (MCE), using sampling pumps calibrated at 2 liters per minute (Lpm). The analysis for lead was conducted using an ultrasonic bath and a portable anodic stripping voltameter instrument according to NIOSH Method 7701.[2]

Elements

Element air samples were collected on 37–mm diameter (0.8–µm pore-size) MCE filters, using sampling pumps calibrated at 2 Lpm. Air samples for elements were quantitatively analyzed by the NIOSH contract laboratory for silver, aluminum, arsenic, barium, beryllium, calcium, cadmium, cobalt, chromium, copper, iron, lithium, magnesium, manganese, molybdenum, sodium, nickel, phosphorus, lead, platinum, selenium, tellurium, thallium, titanium, vanadium, yttrium, zinc, and zirconium using a Thermo Jarrell Ash ICAP–61 inductively coupled argon plasma emission spectrometer according to NIOSH Method 7300.[2]

Total Dust and Respirable Dust

Air samples for total dust were collected on a tared 37–mm diameter, (5–µm pore-size) polyvinyl chloride (PVC) filter at a calibrated flow rate of 1.5 Lpm. The filter was gravimetrically analyzed (filter weight) by the NIOSH contract laboratory according to NIOSH Method 0500.[2] Air samples for respirable dust were collected with a tared 37–mm diameter 5–µm PVC filter in conjunction with a 10–mm cyclone at a calibrated flow rate of 1.7 Lpm. The filter was gravimetrically analyzed by the NIOSH contract laboratory according to NIOSH Method 0600.[2]

Bulk Samples

Bulk samples of the fly ash from inside the boiler were analyzed for elements using a Thermo Jarrell Ash ICAP–61E inductively coupled plasma emission spectrometer controlled by a digital DEC station personal computer in accordance with NIOSH Method 7300 for bulk samples.[2] These bulk samples were also analyzed for quartz and cristobalite using x-ray diffraction in accordance to NIOSH Method 7500[2] with the following modifications: (1) the filters were dissolved in tetrahydrofuran rather than being ashed in a furnace, and (2) standards and samples were run concurrently and an external calibration curve was prepared from the integrated intensities rather than using the suggested normalized procedure in the method.

Bulk samples of pipe insulation in the janitors' closet and gym/school utility tunnel were analyzed for asbestos by polarized light microscopy according to NIOSH Method 9002.[2] In addition to bulk samples of pipe insulation, one area air sample was collected at the entrance to the boys dormitory utility tunnel. This sample was collected on a 37–mm diameter (0.8–µm pore-size) MCE membrane filter; using a sampling pump calibrated at 3 Lpm. The sample was analyzed for total fibers by phase contrast microscopy according to NIOSH method 7400.[2]

Confined Space

A PhD Gas Detector (Model 1600, Biosystems, Inc. Middlefield, Connecticut) was used to monitor the percent of oxygen, lower explosive limits, carbon monoxide (CO), and hydrogen sulfide inside the boiler while the worker was removing fly ash.

Ventilation

Measurements of air velocity within the ventilation system used during the boiler cleaning process were collected with a velometer (TSI Incorporated, St. Paul, Minnesota).

Medical Evaluation

Prior to the NIOSH HHE request, the Indian Health Service (IHS) conducted a routine environmental survey at the Marty Indian School. During this evaluation, the boilers were identified by IHS representatives as a potential source of lead exposure to workers as well as to the environment. The IHS performed finger-stick blood lead testing in two of the workers in the boiler room. One of the samples showed an elevated blood lead. There was concern that the sample may have been contaminated by lead on the skin's surface, so the two employees underwent a second blood lead evaluation and these levels were within normal limits. Agency for Toxic Substances and Disease Registry (ATSDR) representatives were contacted by the IHS to evaluate the potential for lead exposure from the soil and ash in the area surrounding the school. ATSDR decided to test blood lead levels in the children and employees of the school. Testing was offered to all employees, but the workers in the boiler room declined to be tested by ATSDR since they had already been tested twice and had obtained results showing their blood lead levels (BLLs) to be within normal limits.

NIOSH investigators reviewed the results of blood lead testing conducted in March 1998 by ATSDR. The following groups were included in this testing: (1) children aged 6 years or less who either attended school or pre-school programs at the Marty Indian School or who lived in the neighborhood near the school at the time of the study, (2) children older than 6 years who worked in the shop area at the time of the study, and (3) adult employees at the school. None of the adults who worked in the shop or boiler area were tested. Blood samples were collected from 58 children and 41 adults on March 3–4, 1998. The job titles for the adults tested in the ATSDR study included teachers, bus drivers, secretaries, and janitors.

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, which 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] NIOSH encourages employers to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required 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 higher exposures over the short-term.

For some substances, a biological marker exists that can be used in workplace exposure investigations or studies. In order to measure these markers, a biologic specimen (e.g., exhaled breath, blood, or urine) must be obtained from the participating worker through informed consent. A biological marker can measure acute or chronic exposures, provide an estimation of the dose of a substance in the body or an organ, integrate exposures from more than one exposure route into a dose estimation, measure damage to a target cell and/or organ, or indicate the presence of a disease process. Two sources of reference values for biological markers are the ACGIH Biological Exposure Indices (BEIs®)[4] and the various guidelines developed by the World Health Organization (WHO). In addition, the clinical medicine literature contains reference values for tests used by practicing physicians.

Lead

Lead is ubiquitous in U.S. urban environments due to the widespread use of lead compounds in industry, gasoline, and paints during the past century. Exposure to lead occurs via inhalation of dust and fume, and ingestion through contact with lead–contaminated hands, food, cigarettes, and clothing. Absorbed lead accumulates in the body in the soft tissues and bones. Lead is stored in bones for decades, and may cause health effects long after exposure as it is slowly released in the body.

Symptoms of lead exposure include weakness, excessive tiredness, irritability, constipation, anorexia, abdominal discomfort (colic), fine tremors, and "wrist drop."[6,7,8] Overexposure to lead may also result in anemia, damage to the kidneys, high blood pressure, impotence, infertility, and reduced sex drive in both sexes. An individual's BLL is a good indication of recent exposure to, and current absorption of lead.[9] The frequency and severity of symptoms associated with lead exposure generally increase with the BLL.

The overall geometric mean BLL for the U.S. adult population (ages 20–74 yrs) declined significantly between 1976 and 1991, from 13.1 to 3.0 micrograms per deciliter of blood (µg/dL). This decline is most likely due to the reduction of lead in gasoline. More than 90% of adults now have a BLL of <10 µg/dL, and more than 98% have a BLL <15 µg/dL.[10]

Under the OSHA general industry lead standard (29 CFR 1910.1025), the PEL for airborne exposure to lead is 50 micrograms per cubic meter (µg/m^3) for an 8–hour TWA.[11] The standard requires lowering the PEL for shifts exceeding 8 hours, medical monitoring for employees exposed to airborne lead at or above the action level of 30 µg/m^3 (8–hour TWA), medical removal of employees whose average BLL is 50 µg/dL or greater, and economic protection for medically removed workers. Medically removed workers cannot return to jobs involving lead exposure until their BLL is below 40 µg/dL. The OSHA interim final rule for lead in the construction industry (29 CFR 1926.62) provides an equivalent level of protection to construction workers. The ACGIH® has a TLV for lead of 50 µg/m^3 (8–hour TWA), with worker BLLs to be controlled at or below 30 µg/dL, and designation of lead as an animal carcinogen.[4] The U.S. Public Health Service (PHS) has established a goal, by the year 2000, to eliminate all occupational exposures that result in BLLs greater than 25 µg/dL.[12]

The occupational exposure criteria (above) are not protective for all the known health effects of lead. For example, studies have found neurological symptoms in workers with BLLs of 40 to 60 µg/dL, and decreased fertility in men at BLLs as low as 40 µg/dL. BLLs are associated with increases in blood pressure, with no apparent threshold through less than 10 µg/dL. Fetal exposure to lead is associated with reductions in gestational age, birth weight, and early mental development with maternal BLLs as low as 10 to 15 µg/dL.[13] Men and women who are planning to have children should limit their exposure to lead.

In homes with a family member occupationally exposed to lead, care must be taken to prevent "take home" of lead; that is, lead carried into the home on clothing, skin, hair, and in vehicles. High BLLs in resident children, and elevated concentrations of lead in the house dust, have been found in the homes of workers employed in industries associated with high lead exposure.[14] Particular effort should be made to ensure that children of persons who work in areas of high lead exposure receive a BLL test.

Lead in Surface Dust and Soil

Lead-contaminated surface dust and soil represent potential sources of lead exposure, particularly for young children. This may occur either by direct hand-to-mouth contact, or indirectly from mouth contact with contaminated clothing, cigarettes, or food. Previous studies have found a significant correlation between resident children's BLLs and house dust lead levels.[15] There is currently no federal standard which provides a permissible limit for lead contamination of surfaces in occupational settings. As required by Section 403 of the Toxic Substances Control Act (TSCA), the Environmental Protection Agency (EPA) is in the process of developing a rule to address hazards from lead-contaminated dust and soil in and around homes.

The EPA currently recommends the following clearance levels for surface lead loading be met after residential lead abatement or interim control activities: uncarpeted floors, 100 micrograms per square foot (µg/ft^2); interior window sills, 500 µg/ft^2, and window wells, 800 µg/ft^2.[16] These levels have been established as achievable through lead abatement and interim control activities, and they are not based on projected health effects associated with specific surface dust levels.

The EPA currently recommends a strategy of scaled responses to soil lead contamination, depending upon lead concentrations and site-specific factors. When lead concentrations exceed 400 parts per million (ppm) in bare soil, the EPA recommends further evaluation and exposure reduction activities be undertaken, appropriate to the site-specific level of risk. If soil lead concentrations exceed 5000 ppm, the EPA recommends permanent abatement of contaminated soil.[16]

Childhood Exposure to Lead

The adverse effects of lead on children and fetuses include decreases in intelligence and brain development, developmental delays, behavioral disturbances, decreased stature, anemia, decreased gestational weight and age, and miscarriage or stillbirth. Lead exposure is especially devastating to fetuses and young children due to potentially irreversible toxic effects on the developing brain and nervous system.[13]

No threshold has been identified for the harmful effects of lead in children: The Centers for Disease Control and Prevention (CDC) currently recommends a multi-level approach to defining and preventing childhood lead poisoning, based on BLL screening.[17] The CDC recommends that BLLs in children aged 6 months to 6 years should not exceed 10 µg/dL. The BLLs and corresponding actions which CDC has recommended are: $\geq$10 µg/dL, community prevention activities; $\geq$15 µg/dL, individual case management including nutritional and educational interventions and more frequent screening; $\geq$20 µg/dL, medical evaluation, environmental investigation, and remediation. Additionally, environmental investigation and remediation are recommended for BLLs of 15–19, if such levels persist. A national survey found that the geometric mean BLL for children ages 1–11 ranged from 2.5–4.1 µg/dL, with the highest mean BLL among children aged 1–2 years.[18] However, it was estimated from the survey that 8.9% of U.S. children under 6 years, or about 1.7 million children, have elevated BLLs (≥ 10 µg/dL).

Inorganic Arsenic

NIOSH recognizes inorganic arsenic as a respiratory and skin carcinogen.[19,20,21] Inorganic arsenic causes skin lesions, peripheral nerve damage (neuropathy), anemia, reduced peripheral circulation, and increased mortality due to cardiovascular failure in workers who have been exposed to inorganic arsenic through inhalation, ingestion, or dermal exposure.[22]

RESULTS

Industrial Hygiene Evaluation

Lead

All qualitative wipe samples collected for lead in the plumbing shop and machine shop areas showed non-detectable levels indicating that lead was not present (see Figure 4). Two of the six qualitative wipe samples collected in the boiler room were positive, indicating the presence of lead on some of the surfaces in this room.

All quantitative area air samples collected for lead (using NIOSH method 7701) in the plumbing shop, machine shop, and outside areas resulted in non-detectable concentrations (see Figure 4 for area sample location). The limit of detection (LOD) for the quantitative air samples is 0.1 microgram (µg) of lead per filter. This equates to a minimum detectable concentration (MDC) of 0.18 µg/m^3, based on an air sampling volume of 550 liters.

Area air samples for lead were collected on the left and right side of the boiler and a PBZ sample was collected on the worker during tube cleaning operations (the right side area samples are shown in Figure 1). Lead was not detected on any of the samples during the tube cleaning operations. Therefore, these samples are at or below the MDC for lead using NIOSH Method 7701. A 40–minute PBZ sample was collected for lead and analyzed by NIOSH Method 7701 while the worker removed fly ash inside the boiler. This sample indicated a lead concentration of 1,340 µg/m^3 with an 8–hour TWA of 112 µg/m^3 (assuming no exposure for 440 minutes).

Elements

All area samples collected for elements in the plumbing shop, machine shop, outside areas, and on both sides of the boiler during tube cleaning operations (see Figures 1 and 4 for sample locations) had concentrations well below applicable exposure criteria for each element analyzed (silver, aluminum, arsenic, barium, beryllium, calcium, cadmium, cobalt, chromium, copper, iron, lithium, magnesium, manganese, molybdenum, sodium, nickel, phosphorus, lead, platinum, selenium, tellurium, thallium, titanium, vanadium, yttrium, zinc, and zirconium). However, trace amounts of some elements were found at the air inlet to the air supplied respirator. It is essential that the air supplied respirator air inlet be placed in a location free from contaminants. A PBZ sample collected during the boiler tube cleaning operations also had concentrations well below applicable exposure criteria for each element analyzed.

A 40–minute PBZ sample was collected for elements while the worker removed fly ash inside the boiler. This sample indicated a lead exposure of 2,300 µg/m^3, cadmium exposure of 18 µg/m^3, and a zinc oxide exposure of 12,000 µg/m^3. Arsenic was detected at the limit of quantification (LOQ) on this sample. NIOSH Method 7300 reported an analytical LOQ for arsenic of 5 µg/filter, which equates to a minimum quantifiable concentration (MQC) of 63 µg/m^3, assuming a sample volume of 80 liters. Calcium sulfate was identified as a major ingredient in the bulk samples of fly ash. Therefore, the calcium result given in NIOSH Method 7300 (for elements) was converted to calcium sulfate. Using this method, there was a calcium sulfate concentration of 31,000 µg/m^3 on the PBZ sample collected when cleaning the boiler. The 8–hour TWAs for lead, arsenic, cadmium, zinc oxide, and calcium sulfate are 190 µg/m^3, 5.3 µg/m^3, 1.5 µg/m^3, 1000 µg/m^3, and 2600 µg/m^3, respectively (assuming no exposure for 440 minutes). The TWA results for cadmium, zinc oxide, and calcium sulfate are below applicable occupational evaluation criteria set by NIOSH, OSHA, and ACGIH®. However, the lead 8-hr TWA exceeds the NIOSH REL (100 µg/m^3), OSHA PEL (50 µg/m^3), and the ACGIH TLV® (50 µg/m^3). The arsenic 8-hr TWA exceeds the NIOSH REL ceiling limit of 2 µg/m^3. All other element results on the PBZ sample collected, when cleaning the boiler, were below applicable occupational exposure criteria. See Table 1 for a summary of concentration and TWA results.

Total and Respirable Dust

All area air samples in the plumbing shop, machine shop, outside areas, and on both sides of the boiler during tube cleaning operations, and the personal sample collected during tube cleaning activities indicated concentrations well below applicable criteria for total and respirable dust. No cristobalite or quartz were detected on any of the total or respirable dust samples.

The 39–minute area samples collected for total and respirable dust inside the boiler during cleaning activities had concentrations of 15 mg/m^3 (TWA = 1.3 mg/m^3) and 3 mg/m^3 (TWA = 0.25 mg/m^3), respectively.

Bulk Samples

Bulk samples of the fly ash were collected and analyzed for elements. These indicated that the fly ash is contaminated with various elements (aluminum, arsenic, barium, lead, cadmium, calcium sulfate, chromium, copper, phosphorus compounds [possibly PO_4, P_2O_7, and PO_3 compounds, no elemental phosphorus was found], nickel, magnesium, manganese, molybdenum, and zinc). No cristobalite or quartz was found in the bulk samples.

Bulk samples of pipe insulation in the janitors' closet and gym/school utility tunnel were collected and analyzed for asbestos (these areas have restricted access). The results of these bulk samples indicate that 40 to 50% of the sample material is chrysotile asbestos. Amosite, crocidolite, actinolite/tremolite, and anthophyllite asbestos were not detected.

In addition to bulk samples of pipe insulation, one area air sample was collected at the entrance to the boys' dormitory utility tunnel. The sample was analyzed for total fibers by phase contrast microscopy according to NIOSH Method 7400.[2] Total fibers on this sample were less than the LOD. The analytical LOD for total fibers is 3000 fibers/filter, which equates to a MDC of 0.006 fibers/cubic centimeter (cc), assuming a sample volume of 540 liters.

Confined Space Measurements

The PhD Gas Detector was used to monitor for percent of oxygen, lower explosive limits, CO, and hydrogen sulfide inside the boiler while the worker was removing fly ash. CO and hydrogen sulfide were not detected during the boiler cleaning operation. Oxygen content (21%) and lower explosive limits (0%) remained at safe levels during the entire period the worker was inside the boiler.

Ventilation

Ventilation measurements were collected on the ventilation duct attached to the rotary powered tube cleaner used during boiler tube cleaning operations. The ventilation system included a 2.5 inch diameter hose attached to the rotary powered tube cleaner. An air flow rate of approximately 400 cubic feet per minute (cfm) was measured in the system. This calculates to a velocity of approximately 11,500 feet per minute (fpm) for the ventilation duct on the rotary tube cleaner. The ACGIH ventilation manual recommends a minimum duct velocity of 4500 fpm for lead dust with small chips of material.[23]

Velocity measurements were also collected on the ventilation ducts used to remove the fly ash deposited inside the boiler. Refer to Figure 5 for a diagram of the ventilation system used during cleaning operations inside the boiler. During cleaning operations, two separate ventilation ducts are taken off the same ventilation system. One duct is used to remove fly ash inside the boiler and the other duct is placed at an opening on the opposite side of the boiler to pull air through it while the worker is inside (see Figure 5). The ventilation system in the boiler room was designed with blast gates so that the velocity in the ducts could be adjusted. The blast gates are adjusted to provide adequate ventilation through the duct used to remove fly ash (see Figure 3) and simultaneously allow for general ventilation through the boiler.

During the removal of fly ash inside the boiler, the blast gate on the general ventilation duct was open approximately 50%. For this configuration, the velocity at the opening of the 4" diameter duct used to remove the fly ash was approximately 4400 fpm. The velocity measured through the general ventilation duct was 2700 fpm. There were three openings at the end of the boiler (see Figure 5). Velocity measurements were taken at the openings to determine the total volume of air flowing through the boiler while the worker was inside. The total volume of air calculated from these three openings was approximately 900 cfm.

Smoke was released around the doors of the boiler room to determine if the room was under negative pressure (i.e., air flows into this area from adjacent areas versus air flowing out). The results of the smoke test indicate that the boiler room was under negative pressure during the evaluation. Negative pressure in this room should limit the amount of air moving from the boiler room into adjacent areas and therefore, should reduce the possibility of contaminating other areas.

Medical Evaluation

ATSDR collected blood samples from 58 children and 41 adults at the Marty Indian School on March 3–4, 1998. The BLLs in the children ranged from <3 µg/dL, the detection limit, to 7.3 µg/dL, and in the adults ranged from <3 µg/dL to 4.5 µg/dL. The geometric mean BLL in children was 1.8 µg/dL, and in the adults it was 1.6 µg/dL (using ½ the detection level for non–detectable BLLs).

DISCUSSION

Industrial Hygiene Evaluation

Air sampling results indicate that the ventilation system on the rotary powered tube cleaner was effective at controlling worker exposures while cleaning the tubes on the boiler. All area and PBZ air samples collected during tube cleaning activities and area samples collected in the general shop areas (see Figure 4) indicated airborne concentrations well below established occupational exposure criteria. Bulk sample results indicate that the fly ash is contaminated with various elements. PBZ air samples collected on the worker while removing fly ash inside the boiler indicate that the worker was exposed to concentrations of lead above applicable occupational exposure criteria (NIOSH, OSHA, and ACGIH) and has the potential to be exposed to other elements above occupational exposure criteria (i.e., arsenic, cadmium, calcium sulfate, and zinc oxide) depending on the amount of time spent inside the boiler.

During our evaluation the worker wore disposable coveralls, booties, gloves, hood, and a full–face constant flow supplied air respirator when cleaning the boiler. Respirators are selected based upon the concentration of the compound of interest and the assigned protection factor (APF) of the respirator. An APF is defined as a measure of the minimum anticipated workplace level of respiratory protection that would be provided by a properly functioning respirator or class of respirators to a percentage of properly fitted and trained users.[24] Results of the PBZ air samples collected during our evaluation indicate that any respirator worn inside the boiler during cleaning activities must have an APF of 46 or greater. The full-face constant flow supplied air respirator utilized by the worker during boiler cleaning activities has an APF of 50.

Supplied air respirators deliver clean air through a supply hose to the respirator face piece. It is essential that the air delivered to the respirator be free from contaminants and monitored frequently. For respirators to be worn by employees, an appropriate respiratory protection program must be utilized and be in accordance with OSHA regulation 29 CFR 1910.134.[25] Each worker required to wear a respirator must be medically evaluated and cleared by a physician to wear the specific respirator before performing assigned tasks.

For respirators to be effective and protect workers from harmful exposures they must be selected, inspected, and maintained properly. Respirators should be inspected by the worker prior to and after each use for any defects. Respiratory protective equipment should also be cleaned and disinfected after each use. Respiratory protective devices should never be worn when a satisfactory face seal can not be obtained. There are many conditions that may prevent a good seal between the worker's face and the respirator. Some of these conditions include facial hair, glasses, or an unusually structured face. All workers required to wear a respirator must be properly trained on the selection, use, limitations, and maintenance of the respirator and also be fit-tested to assure a proper seal between the worker's face and the respirator prior to performing work tasks in a contaminated area. All workers should receive annual fit-testing with a quantitative testing device. When not in use, respirators must be stored in a clean environment located away from any source of contamination.

Workers are required to enter the interior of the boiler to remove fly ash that has accumulated during the process of burning used motor oil. The OSHA regulation 29 CFR 1910.146 defines a ***confined space*** as a space that meets these three criteria: (1) is large enough and configured so that an employee can bodily enter and perform any assigned work; (2) is a space that has limited or restricted means for entry or exit (e.g., tanks, vessels, storage bins, vaults, and pits that have limited means of entry); and (3) a space that is not designed for continuous employee occupancy. The standard then defines a ***permit–required confined space*** as a space that meets one or more of the following criteria: (1) a space that contains or has a potential to contain a hazardous atmosphere; (2) a space that contains a material that has the potential for engulfing (surrounding and capturing of a person by a liquid or finely divided solid substance that can be aspirated and cause death or that can exert enough pressure to cause death by strangulation, constriction, or crushing) the person entering the space; (3) the internal configuration of the space is designed in a way that the person entering the space could be trapped or asphyxiated by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross section; or (4) a space that contains any other recognized serious safety or health hazard.[26]

NIOSH defines a confined space as "an area which by design has limited openings for entry and exit, unfavorable natural ventilation which could contain (or produce) dangerous air contaminates, and which is not intended for continuous employee occupancy.[27] The NIOSH criteria for working in confined spaces further classifies confined spaces based upon the atmospheric characteristics such as oxygen level, flammability, and toxicity. As shown in Table 2, if any of the hazards present a situation which is immediately dangerous to life or health (IDLH), the confined space is designated Class A. A Class B confined space has the potential for causing injury and/or illness, but is not an IDLH atmosphere. A Class C confined space is one in which the hazard potential would not require any special modification of the work procedure. Table 3 lists the confined space program elements which are recommended (or must be considered by a qualified person, as defined by the criteria) before entering and during work within confined spaces based on the established hazard classification.

Bulk samples of pipe insulation were obtained from utility tunnels at the school. These samples contained 40 – 50% chrysotile asbestos. The best recommendation for minor damage on insulation is to leave the insulation in place and repair the protective covering.[28] The Asbestos Hazard Emergency Response Act (AHERA) of 1986 created regulatory requirements that pertain to public, private elementary, and secondary school buildings. These regulations require schools to conduct inspections, develop comprehensive asbestos management plans, and select asbestos response actions to deal with asbestos hazards. The AHERA rules do not require schools to remove asbestos-containing materials (ACM).[29] A key element of AHERA regulations requires schools to develop an operations and maintenance (O&M) program if friable ACM are present. The AHERA and O&M requirements also cover non-friable ACM which is about to become friable.[28] Under the AHERA and O&M provisions, schools must carry out specific O&M procedures which provide for clean-up of any ACM releases and help insure the general safety of school maintenance and custodial workers, as well as other school building occupants. The AHERA regulations and O&M requirements mandate that schools employ specific work practices including wet wiping, high efficiency particulate air filter (HEPA) vacuuming, proper waste disposal procedures, and specific training for custodial and maintenance employees who work in buildings with ACM.[28] All procedures outlined in the EPA AHERA regulations (40 CFR 763 Subpart I) must be followed when performing O&M activities at the school.[30]

Medical Evaluation

CDC recommends that BLLs in children aged 6 months to 6 years should not exceed 10 µg/dL.[17] None of the children's BLLs reported in the ATSDR study exceeded this level. In addition, in the third National Health and Nutrition Examination Survey (NHANES), the geometric mean BLL in the United States was 4.1 µg/dL in children 1–2 years of age, and 3.4 µg/dL in children 3–5 years of age.[18] The geometric mean blood lead concentration in the children in the ATSDR study was 1.8 µg/dL, below all of the geometric means found in the NHANES survey.

The OSHA action level for blood lead in adults with occupational exposure to lead is 40 µg/dL. None of the BLLs reported in the adults in the ATSDR study at the Marty Indian School exceeded 10 µg/dL. However, blood lead samples were not collected from the employees who work in the shop or boiler area.

CONCLUSIONS

All area and PBZ air samples collected during tube cleaning activities and area samples collected in the general shop areas (see Figure 4) indicated air concentrations of lead, elements, and particulate that were well below established occupational exposure criteria. PBZ air samples collected on the worker removing fly ash inside the boiler indicate that the worker was exposed to concentrations of lead above applicable occupational exposure criteria (NIOSH, OSHA, and ACGIH) and has the potential to be exposed to other substances above occupational exposure criteria (i.e., arsenic, cadmium, calcium sulfate, and zinc oxide) depending on the amount of time spent inside the boiler.

The ventilation duct used to remove fly ash inside the boiler was in close proximity of the ACGIH recommended minimum duct velocities for removal of lead dust with small chips of material.[23] The minimum duct velocity recommended by ACGIH insures that lead-containing material will not accumulate in the ventilation system, and thus will not deteriorate the performance of the ventilation system. A ventilation duct was also used to provide general ventilation in the boiler during cleaning activities. The worker is required to scrape and brush fly ash off the inside walls of the boiler, and therefore, high concentrations of various substances (i.e., lead, cadmium, arsenic, calcium sulfate, and zinc) were measured. To help control these exposures the following recommendations are provided.

RECOMMENDATIONS

1. During the cleaning activities inside the boiler, the worker wore a full-face constant flow airline respirator, disposable coveralls, booties, gloves, and hood. Based on the exposures measured during this evaluation, the worker should continue to wear this personal protective equipment (PPE) whenever performing fly ash removal activities inside the boiler. The worker should also continue to wear disposable coveralls, booties, gloves, and hood when performing tube cleaning activities or any cleaning activity involving potential contact with fly ash.

Clothing worn under the disposable coveralls (during cleaning activities) may come into contact with fly ash material. A laundering service should be provided to clean any potentially contaminated work clothing. The operators of the laundering service should be informed that the clothes may be contaminated with the various elements found in the fly ash. Work clothing that has the potential to be contaminated with fly ash material should not be worn in the worker's car or home.

Trace amounts of some elements were found at the clean air inlet to the air supplied respirator. It is essential that the clean air inlet be placed in a location free from contaminants.

2. The worker used brushes and scraping devices to remove fly ash on the inside walls of the boiler. The dislodged fly ash is removed by a ventilation duct. To help reduce dust concentrations during brushing and scraping activities, a brush attachment (such as on a vacuum cleaner) could be attached to this ventilation exhaust system. This will aid in the process of removing the fly ash and should reduce dust concentrations by applying the ventilation directly to the fly ash removing tool.

3. After the fly ash is removed from the boiler, it is transported outside to a street sweeper. The street sweeper then discharges the fly ash into a smoke stack, where the fine particles are released into the ambient environment and large particles settle to the bottom of the smoke stack (see Figure 2). The school should contract an environmental engineering consultant firm to evaluate the adequacy of this system, and if necessary, design a new system that provides adequate duct velocities to remove fly ash and assure that it's disposal is in compliance with environmental regulations.

4. Our evaluation indicates that the boiler may best fit the criteria outlined in the toxicity parameter of a Class B confined space (see Table 2). Therefore, we recommend that the checklist for a Class B confined space (see Table 3) be followed before entry into the boiler.

5. No eating, drinking, or smoking should be allowed in the work areas. Eating and drinking should be restricted to designated areas away from contaminants. Smoking, if permitted, should be restricted to a dedicated enclosed area ventilated to the outdoors.[31] Prior to eating, drinking, smoking, or going home workers should change out of contaminated clothing and shower to remove any fly ash they may have come into contact with.

6. Housekeeping practices should be improved to help eliminate the possibility of cross contamination of hazardous materials (e.g., lead) to areas adjacent to the boiler room. Dry-sweeping in the boiler room should be prohibited to prevent lead contaminated dust from becoming airborne, which would increase workers' exposures. Only wet clean-up methods (i.e., mopping) or vacuuming with an approved HEPA-filtered vacuum should be allowed during clean-up activities. Wet clean-up methods should also be used in the plumbing and machine shop areas to help reduce the amount of dust in the air. Wet clean-up methods should not be used in any area where they may cause a potential electrical or explosion hazard.

7. For the children and adults who had their blood tested in the ATSDR study, the BLLs were below levels requiring medical or environmental intervention. However, employees who work in the shop or boiler area did not participate in this study. Air lead monitoring conducted during the NIOSH evaluation showed that personal air lead TWA results (while removing fly ash inside the boiler) exceeded the NIOSH REL (<100 $\mu g/m^3$), OSHA PEL (50 $\mu g/m^3$), and ACGIH TLV (50 $\mu g/m^3$). Therefore, personnel who work in this area should have their BLLs monitored in accordance with the OSHA lead standard.[11]

The OSHA lead standard requires lowering the PEL for shifts exceeding 8 hours, medical monitoring for employees exposed to airborne lead at or above the action level of 30 $\mu g/m^3$ (8–hour TWA), medical removal of employees whose average BLL is 50 µg/dL or greater, and economic protection for medically removed workers. Medically removed workers cannot return to jobs involving lead exposure until their BLL is below 40 µg/dL.[11] Lead monitoring programs need to be implemented to assure that the requirements outlined in the OSHA lead standard are satisfied.

8. During the time of our evaluation, the fuel source for the boilers was used motor oil. Since the evaluation, the school has decided to use heating fuel oil as a substitute. A follow-up survey should be conducted to evaluate worker exposures after the fuel source has been switched to heating fuel oil. The fly ash (accumulated in the boilers as a result of burning heating fuel oil) should be cleaned out of the boilers two or three times before conducting a follow-up survey to re-evaluate worker exposures. This should provide sufficient removal of any residual fly ash that may still be in the boilers as a result of burning used motor oil. The follow-up survey should be conducted by a qualified industrial hygienist.

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Table 1
HETA 98–0124
Marty, South Dakota
Personal sample result during fly ash removal inside boiler

Element	Concentration (µg/m^3)	8-hr TWA (µg/m^3)	NIOSH REL (µg/m^3)	OSHA PEL (µg/m^3)	ACGIH TLV® (µg/m^3)
Lead	2,300	190	<100	50	50
Arsenic	63 (MQC)	5.3	2 (ceiling limit)*	10	10
Cadmium	18	1.5	10*	5	10
Zinc Oxide	12,000	1,000	5,000	15,000	10,000
Calcium Sulfate	31,000	2,600	10,000	15,000	10,000

*These agents are recommended by NIOSH to be treated as potential occupational carcinogens. NIOSH recommends that exposures to these agents be controlled to the lowest feasible concentration.[3]

Table 2
HETA 98-0124
Marty, South Dakota
CONFINED SPACE CLASSIFICATION TABLE

Parameters	**Class A**	**Class B**	**Class C**
Characteristics	Immediately dangerous to life – rescue procedures require the entry of more than one individual fully equipped with life support equipment – maintenance of communication requires an additional standby person stationed within the confined space	Dangerous, but not immediately life threatening – rescue procedures require the entry of no more than one individual fully equipped with life support equipment – indirect visual or auditory communication with workers	Potential hazard – requires no modification of work procedures – standard rescue procedures – direct communication with workers, from outside the confined space
Oxygen	16% or less *(122 mm Hg) or greater than 25% *(190 mm HG)	16.1% to 19.4% *(122 – 147 mm Hg) or 21.5% to 25% (163 – 190 mm Hg)	19.5 % – 21.4% *(148 – 163 mm Hg)
Flammability Characteristics	20% or greater of LFL	10% – 19% LFL	10% LFL or less
Toxicity	**IDLH	greater than contamination level, referenced in 29 CFR Part 1910 Sub Part Z – less than **IDLH	less than contamination level referenced in 29 CFR Part 1910 Sub Part Z

* Based upon a total atmospheric pressure of 760 mm Hg (sea level)
** Immediately Dangerous to Life or Health – as referenced in NIOSH Registry of Toxic Effects of Chemical Substances, Manufacturing Chemists data sheets, industrial hygiene guides or other recognized authorities.

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Table 3
HETA 98-0124
Marty, South Dakota
CHECK LIST OF CONSIDERATIONS FOR ENTRY, WORKING IN AND EXITING CONFINED SPACES

ITEM	CLASS A	CLASS B	CLASS C
1. Permit	X	X	X
2. Atmospheric Testing	X	X	X
3. Monitoring	X	0	0
4. Medical Surveillance	X	X	0
5. Training of Personnel	X	X	X
6. Labeling and Posting	X	X	X
7. Preparation			
Isolate/lockout/tag	X	X	0
Purge and ventilate	X	X	0
Cleaning Processes	0	0	0
Requirements for special equipment/tools	X	X	0
8. Procedures			
Initial plan	X	X	X
Standby	X	X	0
Communications/observation	X	X	X
Rescue	X	X	X
Work	X	X	X
9. Safety Equipment and Clothing			
Head protection	0	0	0
Hearing protection	0	0	0
Hand protection	0	0	0
Foot protection	0	0	0
Body protection	0	0	0
Respiratory protection	0	0	
Safety belts	X	X	X
Life lines, harness	X	0	
10. Rescue Equipment	X	X	X
11. Recordkeeping/Exposure	X	X	

X = indicates requirement
0 = indicates determination by the qualified person

NIOSH [1979]. Criteria for a recommended standard: working in confined spaces. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Cente
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Figure 1. Worker cleaning boiler tubes with ventilated rotary powered tube cleaner.

Figure 2 street sweeper and smoke stack located outside Boiler Shop.

Figure 3. Worker cleaning inside the boiler with ventilation duct.

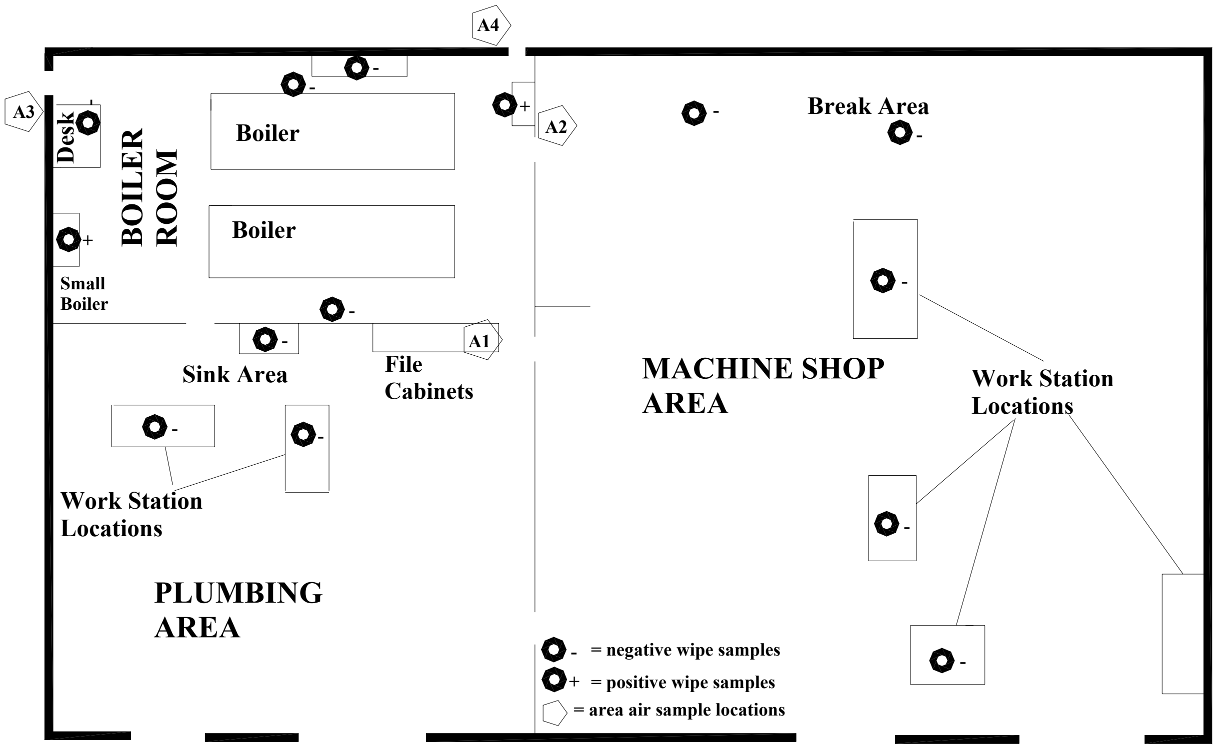

Figure 4. Area air sample and wipe sample locations.

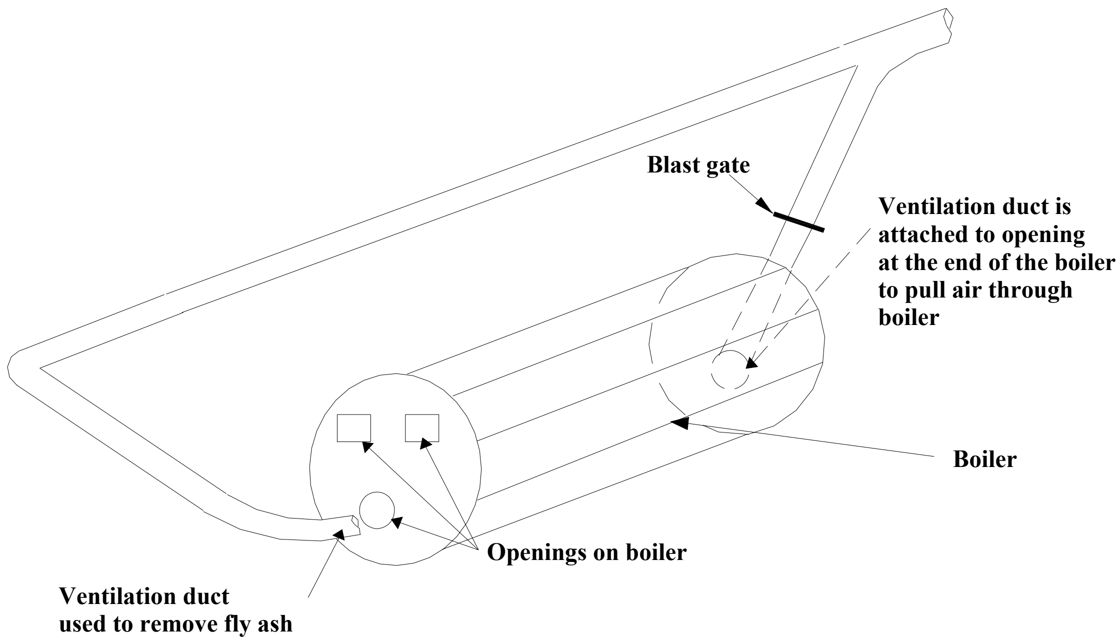

Figure 5. Diagram of boiler and ventilation system.

National Institute for Occupational Safety and Health Evaluation of Worker Exposures During the Boiler Cleaning Process

What NIOSH Did

- Tested air samples for lead and other elements during the boiler cleaning process
- Tested samples of the fly ash for elements
- Tested samples of pipe insulation for asbestos
- Reviewed results of previous blood lead tests

What NIOSH Found

- Air sampling results indicate worker overexposure to lead and arsenic when cleaning the inside of the boiler
- Fly ash was contaminated with toxic substances
- Engineering controls used during the tube cleaning process effectively controlled worker exposure
- Pipe insulation contained chrysotile asbestos
- None of the children's or adult's blood lead levels were high, but blood was not collected from workers in the boiler area

What Marty Indian School Managers Can Do

- Continue to provide the worker cleaning the boiler with personal protective equipment (respirator, disposable coveralls, booties, gloves, and hood)
- Develop a confined space program for entry into the boilers
- Make sure EPA regulations involving asbestos are followed
- Hire an engineering consultant to evaluate the ventilation system
- Test the blood of the workers who clean the boilers for lead in accordance with OSHA lead standard
- Make sure worker exposures are re-evaluated after the fuel for the boilers is switched to heating fuel oil
- Provide a laundry service for any work clothing that has come into contact with fly ash material

What the Marty Indian School Employees Can Do

- Wear personal protective equipment when cleaning boilers
- Make sure to use ventilation controls when cleaning boilers
- Try to avoid stirring up fly ash dust
- Be sure to remove dirty personal protective equipment and shower before eating, drinking, or smoking
- Before going home, shower and change into clean clothes (clothing that has not come into contact with fly ash material)
- Do not wear any clothing that has come into contact with fly ash material in your car or home
- Continue to wear disposable coveralls, booties, gloves, and hood when performing any activity involving potential contact with fly ash
- Do not wash work clothes at home
- Do not use a broom to clean work areas. Use a wet mop (do not use wet methods where electrical or explosion hazards exist) or special vacuum cleaner equipped with a high-efficiency particulate air (HEPA) filter

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