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**HETA 94-0273-2556**  
**Bruce Mansfield Power Station**  
**Shippingport, Pennsylvania**

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**Dino A. Mattorano**

## PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer 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 Dino A. Mattorano, of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Eric J. Esswein and Dave Marlow. Desktop publishing by Kate L. Marlow.

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**Health Hazard Evaluation Report 94-0273-2556**  
**Bruce Mansfield Power Station**  
**Shippingport, Pennsylvania**  
**January 1996**

Dino A. Mattorano

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## SUMMARY

In May 1994, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) at the Bruce Mansfield Power Station in Shippingport, Pennsylvania. The evaluation was requested by the Plumbers and Steamfitters Union Local 47. The request concerned potential exposures to arsenic and other heavy metals encountered by workers during the rebuilding of the coal-fired boilers.

On January 10 and 11, 1995, NIOSH conducted a site visit at the Bruce Mansfield Power Station. The study focused on 33 plumbers and steamfitters. Forty-five personal breathing zone (PBZ) samples for metals, 12 PBZ samples for respirable dust and silica, 8 bulk fly ash samples, and 11 hand wipe samples were collected during the survey. Employees removed retractable soot blowers and boiler drains located on the exterior of the boiler during the air monitoring. Employees worked six 10-hour workdays which equates to a 60-hour workweek. Because of this increase of hours worked per week, the evaluation criteria presented in this report has been adjusted.

The detectable arsenic concentrations (18 of 43) ranged from 0.30 to 31 micrograms arsenic per cubic meter of air ( $\mu\text{g}/\text{m}^3$ ); three samples were over the adjusted Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) of  $5.6 \mu\text{g}/\text{m}^3$ . The detectable beryllium concentrations (11 of 43) ranged from 0.02 to  $0.04 \mu\text{g}/\text{m}^3$  which were all below the PEL. The detectable cadmium concentrations (7 of 43) ranged from 0.17 to  $2.5 \mu\text{g}/\text{m}^3$  which were below the adjusted OSHA PEL of  $2.8 \mu\text{g}/\text{m}^3$ . The detectable lead concentrations (12 of 43) ranged from 1.7 to  $182 \mu\text{g}/\text{m}^3$  with one sample above the adjusted OSHA PEL of  $28 \mu\text{g}/\text{m}^3$ . Crystalline silica (quartz and cristobalite) were below the minimum detectable concentrations (MDCs) of 0.01 and  $0.02 \text{mg}/\text{m}^3$ , respectively. The bulk fly ash analysis revealed that fly ash collected from inside the boiler is consistent with the fly ash collected from working surfaces on the exterior of the boiler. Hand wipe samples collected to evaluate the potential for contaminant hand to mouth contact, showed that employees can be exposed to arsenic and other metals through ingestion.

A portion of the air samples for arsenic, beryllium, and lead, exceeded relevant exposure criteria during the rebuilding of the coal-fired boiler. Recommendations are made to improve housekeeping procedures to reduce the amount of fly ash on working surfaces and to improve work practices.

**Keywords:** SIC 4911 (Electric services) electricity generation, coal-fired power plant, coal-fired power station, fly ash, arsenic, heavy metals, crystalline silica, lead, beryllium

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## INTRODUCTION

In May 1994, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) at the Bruce Mansfield Power Station (BMPS) in Shippingport, Pennsylvania. The evaluation was requested by the Plumbers and Steamfitters (PSF) Union Local 47. The PSF were affiliated with Babcock and Wilcox (B&W) Construction Company. The request concerned potential exposures to arsenic and other heavy metals encountered by workers during the rebuilding of the coal-fired boilers.

On January 9, 1995, the NIOSH evaluation began with an opening conference attended by representatives from management, union, and the contractor to discuss the purpose and scope of the HHE. Following this meeting, a walk-through survey of boiler #2 was conducted to identify specific work areas and job tasks of the PSF employees and to devise an air sampling scheme. On January 10 and 11, 1995, personal breathing zone (PBZ) samples were collected for metals, respirable dust, and silica. Bulk fly ash samples and employee hand wipe samples were also collected during this time. On March 23, 1995, an interim letter was sent to representatives from the PSF union, B&W Construction Company, and Pennsylvania Power reporting the environmental monitoring results.

## BACKGROUND

The Bruce Mansfield Power Station – constructed and operated by Pennsylvania Power Company (Penn Power) – is located 25 miles north of Pittsburgh, Pennsylvania, on a 473-acre site, along the southern bank of the Ohio river, in Shippingport, Pennsylvania. Construction began in 1971 and was completed in 1980. The power station consists of three coal-burning units and has a net generating capacity of 2,360 Megawatts. At full capacity, the BMPS can convert 24,000 tons of coal per day into 56 million kilowatt-hours of electricity. The make-up of the coal averages 4 percent sulfur and 12 percent ash content. Each unit's supercritical,

once-through boiler is designed to deliver approximately 6.5 million pounds of steam per hour at 1,005 degrees Fahrenheit and 3,785 pounds per square inch gauge.

Boiler #2—a 17-story structure suspended from overhead steel rafters—is constructed of several thousand feet of water-wall tubes with an exterior fiberglass insulation liner that is covered with aluminum sheet metal siding. Inside the boiler there are several thousand feet of pendent water tubes. Platen superheater and finishing superheater water tubes are located on the burner side of the boiler; and primary superheater, reheater, and economizer water tubes are located on the gas side of the boiler. On floors four through seven, there are 32 coal burners which individually weigh approximately one ton and are six feet in diameter, including the flange. Each burner receives pulverized coal through carbon-steel pipes. Fuel oil is used to ignite the pulverized coal. Wall soot blowers, which extend approximately one foot into the boiler, use pressurized air to blow ash off the water-wall tubes on the burner side. Retractable soot blowers, which are located on the gas side, extend several feet into the boiler to blow ash off the water tubes and then retract out of the boiler.

In January 1995, boiler #2 was shut down for maintenance. Penn Power and B&W construction company planned to remove and replace 32 coal burners and the reheater and economizer water tubes over the scheduled 15 week outage. Approximately 350-400 contract employees and almost 50 Penn Power employees were on site at the BMPS during this outage and several building trades were represented; however, the focus of this HHE was the 33 contract PSF employees. Information received during the opening conference and observations made by NIOSH investigators revealed that the following activities would be performed during the outage. This list may not reflect all building trades activities. The PSF job tasks are presented in bold italics.

- 1) ***disconnect original ash hopper drains and connect temporary ash hopper drains***
- 2) power wash interior of boiler

- 3) remove and replace fiberglass insulation and aluminum siding
- 4) ***remove burner face (coal pipe, fuel oil lines, air lines)***
- 5) remove and replace burners
- 6) ***remove and replace boiler drains***
- 7) ***remove and replace wall and retractable soot blowers***
- 8) ***run 2 inch air hose for pneumatic equipment***
- 9) build scaffolding on interior of boiler
- 10) remove and replace reheater and economizer water tubes
- 11) ***install two inch bottom ash hopper refractory cooling water supply and return pipe***

According to the contractor, initial clearance air monitoring results were below the OSHA PEL for arsenic. Contract employees were not required to use respiratory protection unless working in designated lead areas, since Penn Power had previously identified pipes and steel structures that contained lead paint. When cutting and/or welding on these painted materials, employees were required to use tyvek suits and half-face respirators with high efficiency particulate air (HEPA) filters. Eight PSF employees had respirator fit tests and were in a respiratory protection program. The rest of the PSF employees had disposable dust/mist particulate respirators available to use at their own discretion. However, these employees were not required to be in a respiratory protection program. The boiler outage was on a strict time schedule. Thus, the PSF employees worked six 10-hour work shifts per week from the second week of January until the end of the outage, which lasted approximately three months.

## EVALUATION CRITERIA

To assess the hazards posed by workplace exposures, NIOSH investigators use a variety of environmental evaluation criteria. These criteria suggest exposure levels to which most workers may be exposed for a

working lifetime without experiencing adverse health effects. However, not all workers will be protected from adverse health effects if their exposures are maintained below these occupational health exposure criteria. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, previous exposures, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, or with medications or personal habits of the worker (such as smoking, etc.) to produce health effects even if the occupational exposures are controlled to the limit set by the evaluation criterion. These combined effects are often not considered by the chemical specific evaluation criteria. Furthermore, many substances can be appreciably absorbed by direct contact with the skin and thus potentially increase the overall exposure and biologic response beyond that expected from inhalation alone. Finally, evaluation criteria may change over time as new information on the toxic effects of an agent become available. Because of these reasons, it is prudent for an employer to maintain worker exposures well below established occupational health criteria.

The primary sources of evaluation criteria for the workplace are: NIOSH Criteria Documents and recommended exposure limits (RELs),<sup>1</sup> the Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs),<sup>2</sup> and the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values (TLVs).<sup>3</sup> The objective of these criteria for chemical agents is to establish levels of inhalation exposure to which the vast majority of workers may be exposed without experiencing adverse health effects.

Occupational health criteria are established based on the available scientific information provided by industrial experience, animal or human experimental data, or epidemiologic studies. Differences between the NIOSH RELs, OSHA PELs, and ACGIH TLVs may exist because of different philosophies and interpretations of technical information. It should be noted that RELs and TLVs are guidelines, whereas PELs are standards which are legally enforceable. OSHA PELs are required to take into account the technical and economical feasibility of controlling exposures in various industries where the agents are present. The NIOSH RELs are primarily based upon the prevention of occupational disease without assessing the economic feasibility of the affected

industries, and as such, tend to be conservative. A Court of Appeals decision vacated the OSHA 1989 Air Contaminants Standard in *AFL-CIO v OSHA*, 965F.2d 962 (11th cir., 1992); and OSHA is now enforcing the previous 1971 standards (listed as Transitional Limits in 29 CFR 1910.1000, Table Z-1-A).<sup>2</sup> However, some states which have OSHA-approved State Plans continue to enforce the more protective 1989 limits. NIOSH encourages employers to use the 1989 limits or the RELs, whichever are lower.

Evaluation criteria for chemical substances are usually based on the average PBZ exposure to the airborne substance over an entire 8- to 10-hour workday during a 40-hour workweek, expressed as a time-weighted average (TWA). Personal exposures are usually expressed in parts per million (ppm), milligrams per cubic meter (mg/m<sup>3</sup>), or micrograms per cubic meter (µg/m<sup>3</sup>). To supplement the 8-hr TWA where there are recognized adverse effects from short-term exposures, some substances have a short-term exposure limit (STEL) for 15-minute peak periods; or a ceiling limit, which is not to be exceeded at any time. Additionally, some chemicals have a "skin" notation to indicate that the substance may be absorbed through direct contact of the material with the skin and mucous membranes.

## Arsenic

Exposure to inorganic arsenic can produce dermatitis (skin inflammation), keratoses (horny growths on the skin), peripheral neuropathies (diseases of the nerves of the extremities), peripheral vascular diseases (diseases of the arteries and veins of the extremities), and cancer of the skin, liver, and lungs. Arsenic is absorbed primarily via inhalation and ingestion. Ingestion from hand to mouth contact may result in absorption of toxicologically significant amounts of arsenic.<sup>4</sup>

Inorganic arsenic is eliminated from the body through metabolism and urinary excretion. The total amount excreted in urine accounts for about 60% of the absorbed amount. Inorganic arsenic metabolites appear in urine shortly after the start of exposure. The concentration rises slowly during the first days of the exposure, and then levels off. If a worker's exposure on following days is similar, the arsenic concentration in urine remains more or less the same.

The ACGIH TLV for inorganic arsenic is 10 µg/m<sup>3</sup>

as an 8-hr TWA, with the designation of confirmed human carcinogen. The ACGIH Biological Exposure Index (BEI) for arsenic is 50 micrograms per gram (µg/g) of creatinine for inorganic arsenic metabolites in urine measured in workers at the end of the workweek. Since arsenic concentrations in urine are dependent on urine output, they are normalized with reference to creatinine concentration in the sample. Creatinine is usually excreted from the body in urine at a constant rate. Both NIOSH and OSHA consider inorganic arsenic to be a potential occupational carcinogen. The NIOSH REL (ceiling limit) is 2 µg/m<sup>3</sup>, and the OSHA PEL is 10 µg/m<sup>3</sup> as an 8-hr TWA. NIOSH and ACGIH recommend that occupational exposures to arsenic be lowered to the lowest feasible concentration.

Sources of non-occupational exposure to arsenic are drinking water, food, and polluted air.<sup>5</sup> Cigarette smoking is also a source of exposure to arsenic (12 to 42 µg/cigarette).<sup>6</sup> Therefore, arsenic is found in the urine of people who have no occupational exposure. Concentrations of inorganic arsenic and its metabolites in the urine of the general population are usually below 10 micrograms per liter (µg/L) in European countries, but slightly higher in the United States.<sup>7</sup>

## Beryllium

Occupational exposure to compounds of beryllium may cause dermatitis, acute pneumonitis (lung inflammation), and chronic pulmonary granulomatosis (berylliosis - multiple nodular inflammatory lesions) in humans.<sup>8</sup> Various parts of the respiratory tract may be involved, with inflammation of the mucus membrane of the nose, throat, trachea, and bronchi and pneumonitis.<sup>9</sup> The pneumonitis may be fulminating (rapid worsening) following high exposure levels, or less severe, with gradual onset, from lesser exposures.<sup>8,10</sup> A variety of beryllium compounds and some of its alloys have induced malignant tumors of the lung in rats and monkeys and osteogenic sarcoma (disease of the bone) in rabbits. Epidemiologic studies are strongly suggestive of a carcinogenic effect in humans.<sup>11</sup> The NIOSH REL is 0.5 µg/m<sup>3</sup>, the ACGIH TLV is 2 µg/m<sup>3</sup>, and the OSHA PEL is 2 µg/m<sup>3</sup>, expressed as TWAs over an 8-10 hr workday. NIOSH and ACGIH recommend that occupational exposures to beryllium be lowered to the lowest feasible concentration.

## Cadmium

Occupational exposure to cadmium can cause pulmonary irritation and is associated with nephrotoxicity (kidney poisoning). Several inorganic cadmium compounds cause malignant tumors in animals.<sup>8</sup> Most acute intoxications have been caused by inhalation of cadmium oxide fumes that did not provide warning symptoms of irritation and led to fatalities, pneumonitis, and pulmonary edema (accumulation of fluid in the lungs).<sup>12,13</sup> Cadmium exposure has been implicated to increases in prostate and respiratory tract cancer.<sup>14</sup> NIOSH concluded that cadmium and its compounds are potential carcinogens and recommends reducing occupational exposures to the lowest feasible concentration.<sup>1</sup> The ACGIH TLV and OSHA PEL for cadmium are 10 and 5  $\mu\text{g}/\text{m}^3$ , respectively as an 8-hr TWA.

## Lead

Chronic lead exposure has resulted in nephropathy (kidney damage), gastrointestinal disturbances, anemia, and neurologic effects.<sup>8</sup> These effects may be felt as weakness, fatigue, irritability, high blood pressure, mental deficiency, or slowed reaction times. Exposure also has been associated with infertility in both sexes and fetal damage.<sup>15</sup> The OSHA PEL for lead is 50  $\mu\text{g}/\text{m}^3$ , while the current ACGIH TLV is 150  $\mu\text{g}/\text{m}^3$ . The ACGIH has proposed a TLV of 50  $\mu\text{g}/\text{m}^3$  and an animal carcinogen classification on the Notice of Intended Changes.<sup>3</sup> The NIOSH REL is 100  $\mu\text{g}/\text{m}^3$ . NIOSH further stipulates that air concentrations should be maintained at a level so that worker blood lead remains less than 60  $\mu\text{g}$  lead per 100 grams of whole blood.<sup>1</sup> Currently, NIOSH is re-evaluating the lead criteria in light of the information that was not available when the REL was established.

## Titanium Dioxide

Titanium dioxide is a mild pulmonary irritant generally considered to be a nuisance dust.<sup>8</sup> In the lungs of three workers processing titanium dioxide pigment, dust deposit findings indicate that titanium dioxide is a minor pulmonary irritant. Rats repeatedly exposed to concentrations of 10 to 328 million particles per cubic foot of air for up to 13 months showed small focal areas of emphysema, attributable to large deposits of dust.<sup>8</sup> There was no evidence that titanium dioxide produced any specific

lesion.

A two year research study where rats were exposed to 250  $\text{mg}/\text{m}^3$  of titanium dioxide resulted in the development of squamous cell carcinomas in 13 of 74 female rats and in 1 of 77 male rats, as well as a increase in bronchoalveolar adenomas, another type of tumor. No excess tumor incidence was noted at 50  $\text{mg}/\text{m}^3$ . The authors of that study questioned the biologic relevance of these tumors to humans, given the extremely high exposure concentrations, the unusual histology and the location of the tumors, and the absence of metastases (spread of disease from one part of the body to another).<sup>16</sup> The ACGIH TLV for titanium dioxide is 10  $\text{mg}/\text{m}^3$  as an 8-hour TWA.<sup>3</sup> The OSHA PEL is 15  $\text{mg}/\text{m}^3$  as an 8-hour TWA.<sup>2</sup> NIOSH considers titanium dioxide to be a potential occupational carcinogen and recommends that exposures be reduced to the lowest feasible concentration.<sup>1,16</sup>

## Unusual Work Schedules

The above evaluation criteria are based on 8- to 10-hour workdays and 40-hour workweeks. During this outage, employees worked six 10-hour workdays, which equates to a 60-hour workweek. Because of this significant increase of hours worked per week, consideration should be given to modifying the evaluation criteria. The rationale for adjusting occupational exposure limits for unusual work schedules is to assure, as much as possible, that persons on these schedules are placed at no greater risk of injury or discomfort than persons who work a standard 8-hour workday, 40-hour workweek.<sup>17</sup> As a tentative guide, The Brief and Scala Model cited in the ACGIH TLV booklet is intended to apply to work schedules longer than 8-hour workdays or 40-hour workweeks.<sup>18</sup> For example, the ACGIH TLV for arsenic is 10  $\mu\text{g}/\text{m}^3$ . When adjusting this exposure limit based on hours worked per week,

$$\frac{40}{h} \times \frac{168 - h}{128} = \text{TLV reduction factor}$$

h = hours worked per workweek

the adjusted exposure limit is 5.6  $\mu\text{g}/\text{m}^3$ . The PBZ sample results in Tables I and II are compared to the adjusted exposure limits.

## METHODS



The environmental evaluation consisted of collecting full-shift PBZ samples from 27 PSF employees on both January 10 and 11, 1995. NIOSH investigators collected a total of 45 PBZ samples for metals, 2 area air samples for metals, 12 PBZ samples for respirable dust and silica, 11 hand wipe samples, and 8 bulk fly ash samples. In some cases consecutive PBZ samples were collected during any one work shift to prevent particulate overloading.

## Metals

Air samples for metals were collected on 37-millimeter (mm), 0.8  $\mu\text{m}$  pore size cellulose ester membrane filters in clear cassette holders. The filters were attached via flexible Tygon® tubing to personal sampling pumps and the sampling trains were calibrated at a flow rate of 2 liters per minute (Lpm). The samples were analyzed for 28 elements using NIOSH analytical method 7300.<sup>19</sup> The method was modified for microwave digestion and standard matrix matching of samples. A Thermo Jarrell Ash ICAP-61 inductively coupled plasma (ICP) emission spectrometer controlled by a Digital DEC Station 333c personal computer was used for all measurements. The analytical limits of detection (LOD) for arsenic, beryllium, cadmium, lead, and titanium were 0.3, 0.02, 0.2, 2.0, and 0.2  $\mu\text{g}/\text{filter}$ , respectively; which equates to minimum detectable concentrations (MDC) of 0.3, 0.02, 0.17, 1.7, and 0.17  $\mu\text{g}/\text{m}^3$ , respectively, using a 1200 liter sample volume. The analytical limit of quantitation (LOQ) for arsenic, beryllium, cadmium, lead, and titanium are 8.2, 0.12, 0.35, 4.0, and 0.6  $\mu\text{g}/\text{m}^3$ , respectively; which equates to minimum quantifiable concentrations (MQC) of 6.8, 0.1, 0.3, 3.3, and 0.5  $\mu\text{g}/\text{m}^3$ , respectively, using a 1200 liter sample volume. It is important to note that the personal breathing zone air sample results at the end of this document report titanium as titanium dioxide for comparison with the evaluation criteria.

Bulk fly ash samples were collected from areas in and around boiler #2. The exterior samples were collected from surfaces representative of areas where PSF employees worked. The samples were collected in glass vials, labeled, and shipped to the analytical laboratory. The bulk fly ash samples were analyzed for selected metals using NIOSH method 7300 as described above. The analytical LODs for arsenic, beryllium, cadmium, lead, and titanium were 20, 0.3, 1.0, 10, and 2.0  $\mu\text{g}/\text{g}$ , respectively. The LOQs for

arsenic, beryllium, cadmium, lead, and titanium were 81, 1.1, 3.4, 39, and 6  $\mu\text{g}/\text{g}$ , respectively.

Hand wipe samples were collected because the hand wash stations were not operating properly and a majority of the PSFs were smokers, thus increasing the potential for hand to mouth contact. This hand wipe technique is used to quantitatively identify contaminants (metals) on employees' hands. The hand wipe samples were collected on Wash'n Dri® moist disposable towelettes and analyzed for selected metals using NIOSH analytical method 7300 as described above. The LODs for arsenic, beryllium, cadmium, lead, and titanium were 0.4, 0.02, 0.07, 0.4, and 0.09  $\mu\text{g}/\text{wipe}$ , respectively. The LOQs for arsenic, beryllium, cadmium, lead, and titanium were 1.3, 0.05, 0.22, 1.3, and 0.29  $\mu\text{g}/\text{wipe}$ , respectively.

The employee hand wipe samples were collected in three steps. (1) NIOSH investigators supplied Wash'n Dri® towelettes to the PSF employees. (2) PSF employees were instructed to unfold the towelette completely and wipe both hands including palms, the back of the hand, the cuticles, the fingers, and between the fingers continuously for thirty seconds. (3) PSF employees were then instructed to place the towelette into a zip-lock plastic bag held by the NIOSH investigator.

## Respirable Particulate and Silica

The respirable particulate and silica samples were collected on tared 37 mm, 5  $\mu\text{m}$  pore size polyvinyl chloride (PVC) membrane filters mounted in 10 mm nylon Dorr-Oliver cyclones. The filters were attached via flexible Tygon® tubing to personal sampling pumps and the sampling trains were calibrated at a flow rate of 1.7 Lpm. The collected samples were weighed by gravimetric analysis according to NIOSH analytical method 0600<sup>19</sup> with two modifications. The filters were stored in an environmentally controlled room to reduce the stabilization time between tare weighings from 8-16 hours to 5-10 minutes, and the backup pads and filters were not vacuum desiccated. The instrumental precision of the weighings was 0.02 milligrams (mg).

After the gravimetric analysis, the samples were then analyzed for silica (quartz and cristobalite) using x-ray diffraction. NIOSH analytical method 7500<sup>19</sup> was used with the following modifications: (1) 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 normalization procedure. The LODs for quartz and cristobalite for this method were 0.01 mg/sample and 0.015 mg/sample, respectively. The LODs for quartz and cristobalite equate to MDCs of 0.01 and 0.02 mg/m<sup>3</sup>, respectively, using a sample volume of 943 liters.

## RESULTS

### Metals

The air sample results for metals are presented in Tables 1 and 2. Only the results for the metals with the greatest toxicological significance and found at the highest concentrations are presented in these tables.

Approximately 42 percent (18 of 43) of the full-shift PBZ metal samples contained arsenic concentrations above the MDC (0.3 µg/m<sup>3</sup>). The arsenic concentrations ranged from trace levels to 31 µg/m<sup>3</sup>. Three air samples were above the adjusted OSHA PEL of 5.6 µg/m<sup>3</sup>. Twenty-six percent (11 of 43) of the full-shift PBZ metal samples contained beryllium concentrations above the MDC (0.02 µg/m<sup>3</sup>). The beryllium concentrations ranged from trace levels to 0.40 µg/m<sup>3</sup>. Sixteen percent (7 of 43) of the full-shift PBZ metal samples contained cadmium concentrations above the MDC (0.17 µg/m<sup>3</sup>). Cadmium concentrations ranged from trace levels to 2.5 µg/m<sup>3</sup>. Twenty-eight percent (12 of 43) of the full-shift PBZ metal samples contained lead concentrations above the MDC (1.7 µg/m<sup>3</sup>). Lead concentrations ranged from trace levels to 181 µg/m<sup>3</sup>. One air sample was above the adjusted OSHA PEL of 28 µg/m<sup>3</sup>. All 43 of the full-shift PBZ metal samples contained titanium dioxide concentrations above the MDC (0.17 µg/m<sup>3</sup>). Titanium dioxide concentrations ranged from 2.25 to 228 µg/m<sup>3</sup>. It is important to note that NIOSH considers arsenic, beryllium, cadmium, and titanium dioxide potential occupational carcinogens, and recommends that airborne concentrations be reduced to the lowest feasible concentration.

Two PBZ air samples which had large clumps of debris were eliminated from the data set because of particulate overloading of the sample cassettes or possible tampering.

### Respirable Particulate / Silica

The 12 full-shift PBZ air samples collected for respirable particulates had concentrations above the MDC of 0.13 mg/m<sup>3</sup> assuming an average sample volume of 943 liters. The respirable particulate concentrations ranged from 0.15 to 0.51 mg/m<sup>3</sup>. Although low when compared to the OSHA PEL of 5 mg/m<sup>3</sup> or the ACGIH TLV of 3 mg/m<sup>3</sup>, the criteria may not be applicable due to the heavy metal content of the fly ash. The 12 full-shift PBZ air samples collected for respirable particulates were also analyzed for cristobalite silica and quartz silica. The air sample results indicate that airborne concentrations of both cristobalite and quartz silica were below the MDCs of 0.02 and 0.01 mg/m<sup>3</sup>, respectively.

### Bulk Samples

The bulk fly ash analytical results are presented in Table 3. The bulk sample analysis revealed that fly ash collected from the interior of boiler #2 is consistent with the settled dust collected from the exterior of boiler #2, including working surfaces. The contaminants detected in the PBZ air samples were detected in all of the bulk samples except for the coal sample.

### Hand Wipe Samples

The hand wipe analytical results are presented in Table 4 and 5. The results showed that PSF employees may be exposed to arsenic, cadmium, lead, and other heavy metals through ingestion. As mentioned in the Methods section of this report, the hand wash stations were not operating properly and a majority of the PSF employees were smokers, thus increasing the potential for hand to mouth contact.

## DISCUSSION/ CONCLUSION

Prior to the outage, interior surfaces of boiler #2 were washed with a high pressure water system to remove fly ash. The NIOSH investigators were able to inspect several of these interior surfaces, including water tubes that were to be removed, and found them to be remarkably clean except for one specific area

on the eighth floor. After boilermakers removed a section of the water-wall tubes on the west side of the boiler, a large deposit of fly ash remained on the interior economizer tubes. According to the contractor, this area was to be cleaned before the economizer tubes were removed.

It is important to note that effort was taken to clean interior surfaces of the boiler. However, no effort was taken to clean working surfaces on the exterior of the boiler. In general, most working surfaces on or near boiler #2 were covered with settled dust from fly ash and/or coal. In some cases, the settled dust was five to six inches thick. When PSFs removed soot blowers or boiler drains, the settled dust became airborne. The contaminants detected in the air samples were detected in all of the bulk dust samples. Also contributing to the airborne dust concentrations, NIOSH investigators observed non-PSF employees removing aluminum siding and insulation from boiler #2. When removing the large aluminum panels, the employees threw them into piles creating unnecessary airborne dust. The airborne dust migrated to floors above and below this area because of the metal-grated floors of the power station. By implementing good work practices, such as applying a fine mist of water to the panels before moving them or setting the panels down instead of throwing them, airborne dust concentrations can be minimized. Better housekeeping will also reduce airborne dust concentrations.

PBZ air sample results revealed overexposures to arsenic and lead. In addition, hand wipe samples showed the presence of these metals, even when employees had washed their hands prior to sample collection. Thus, hand to mouth contact can contribute to the employees' overall metal exposure. For metals such as arsenic and lead, ingestion is a significant route of exposure, and may lead to the absorption of toxicologically significant quantities of these metals. Lastly, the PSF worked six 10-hour work shifts (60-hour workweek) and the evaluation criteria is based on a 40-hour workweek. As mentioned in the Evaluation Criteria section of this report, the exposure limits should be adjusted to reflect the significant increase in hours worked per week.

On several occasions, NIOSH investigators observed contract employees welding and torch cutting metal throughout the facility. Because of the grated metal floors, sparks and hot metal fell several floors creating a safety hazard for employees working

below. On a few instances, fire-retardant fabric was put down over the metal-grated floor to contain the welding/cutting sparks and hot metal pieces. This is an effective control measure that should routinely be used.

## RECOMMENDATIONS

Based on the air, bulk, and hand wipe sample data, which were in some instances above relevant evaluation criteria, the NIOSH investigators determined that a health hazard from exposures to metals in fly ash existed at the Penn Power station during the rebuilding of the coal-fired boiler. The following recommendations are offered to improve the health and safety conditions at the Bruce Mansfield Power Station during further rebuilding of the boilers.

1. Workers' exposures to arsenic, lead, cadmium, and other heavy metals in fly ash should be reduced through the use of work practices and personal protective equipment. For arsenic, lead, and cadmium, the requirements outlined in the OSHA standards should be followed.<sup>20,21,22</sup> These standards include provisions for periodic exposure monitoring, implementation of engineering and work practice controls where overexposures occur, use of respiratory protection while engineering controls are being implemented or when controls are not sufficient to reduce employee exposures to or below the OSHA PEL, provision of clean protective clothing and lunchroom facilities, establishment of a medical surveillance program, and employee notification, education, and training.
2. Housekeeping procedures should be improved. The bulk sample analysis revealed that fly ash collected from the interior of boiler #2 is similar to the settled dust collected from working surfaces on the exterior of boiler #2. By removing fly ash from working surfaces before work begins, the potential for airborne metal exposures can be reduced. When removing fly ash, dry methods (shoveling and sweeping) should be replaced with wet methods and/or HEPA vacuum-cleaning methods to minimize aerosolization of settled dust.
3. Good work practices should be implemented. For example, when removing exterior aluminum panels from the boiler, employees should set the panels down instead of throwing them into piles creating unnecessary airborne dust. Also, applying a fine

mist of water to the panels before moving them will help minimize the potential for the dust to become airborne.

4. Welding and torch cutting operations should be shielded to prevent optical radiation hazards and contain the sparks and hot metal from falling through the grated floors. The shields should be arranged so that ventilation is not restricted. At a minimum, work practices must conform to OSHA standards 1926.350 - 354.<sup>23</sup>

5. The hand wash stations should be repaired so employees can wash their hands and face prior to eating or smoking. The hand wipe sample results revealed that employees are potentially exposed to arsenic, cadmium, lead, and other heavy metals through ingestion of the fly ash. Smoking and eating in areas where exposure to fly ash can occur should be eliminated. Workers should be required to wash their hands and face prior to eating or smoking.

6. The PSF worked six 10-hour work shifts (60-hour workweek) and the evaluation criteria are based on a maximum 40-hour workweek. As mentioned in the Evaluation Criteria Section of this report, the exposure limits should be adjusted to reflect the significant increase in hours worked per week, as was done in this report.

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**Table 1**  
**Personal Breathing Zone Air Samples for Metals**  
**HETA 94-0273-2556**  
**January 10, 1995**

Job Task / Location (floor)	Sample time (military)	Sample Vol. (liters)	As	Be	Cd	Pb	TiO <sub>2</sub>
			µg/m <sup>3</sup>	µg/m <sup>3</sup>	µg/m <sup>3</sup>	µg/m <sup>3</sup>	µg/m <sup>3</sup>
*boiler drain/ 7th	0704 - 1648	1162	ND	ND	Trace	Trace	4.5
*boiler drain/ 7th	0705 - 1648	1166	ND	ND	ND	3.9	3.7
boiler drain/ 8th	0706 - 1706	1200	Trace	ND	ND	Trace	18.1
soot blower/ 8th	0712 - 1724	1224	ND	Trace	ND	ND	9.1
soot blower/ 8th	1045 - 1703	756	Trace	ND	ND	ND	8.8
soot blower/ 15th	0708 - 1710	1204	Trace	Trace	Trace	ND	7.4
soot blower/ 15th	0709 - 1707	1196	ND	ND	ND	ND	4.1
soot blower/ various	0713 - 1716	1206	ND	ND	ND	ND	6.2
soot blower/ various	0723 - 1657	1148	ND	ND	ND	ND	6.0
soot blower/ various	0723 - 1704	1162	ND	ND	ND	ND	4.3
soot blower/ various	0722 - 1709	1174	ND	Trace	ND	ND	3.1
soot blower/ various	0726 - 1705	1158	26.8	0.11	1.3	181	134
soot blower/ various	0719 - 1701	1164	Trace	Trace	0.37	Trace	17.2
soot blower/ various	0716 - 1700	1110	4.4	ND	ND	3.9	26.6
soot blower/ various	0719 - 1708	1178	ND	ND	ND	ND	2.8
soot blower/ various	0715 - 1704	1178	ND	ND	ND	ND	2.7
soot blower/ various	0710 - 1710	1200	Trace	Trace	ND	ND	9.5
various/ 8th & BM	0715 - 1700	1170	ND	ND	0.48	Trace	11.8
various/ various	0710 - 1658	1176	Trace	ND	ND	ND	5.8
various/ various	0711 - 1650	1158	Trace	Trace	ND	Trace	18.8
lunch room/ 4th	0925 - 1732	974	ND	ND	ND	ND	1.3
lunch room/ 5th	0915 - 1720	970	ND	ND	ND	ND	3.1
**Evaluation Criteria		NIOSH REL	LFC/ 2 C	LFC/ .5	LFC	100	LFC
*** Adjusted		OSHA PEL	5.6	1.1	2.8	28	8,400
*** Adjusted		ACGIH TLV	5.6, A1	1.1, A2	5.6, A2	[28, A3]	5,600
		OSHA PEL	10	2	5	50	15,000
		ACGIH TLV	10, A1	2, A2	10, A2	[50, A3]	10,000

\* Indicates employees worked in lead area

\*\* Evaluation criteria are listed for 8-hour time weighted averages, unless other wise noted

\*\*\* Adjusted occupational exposure limit using the Breif and Scala model<sup>18</sup>

µg/m<sup>3</sup> = micrograms per cubic meter

ND = not detected

Trace = concentration between MDC and MQC

BM = basement

A1 = confirmed human carcinogen

A3 = animal carcinogen

mg/m<sup>3</sup> = milligrams per cubic meter

LFC/ = lowest feasible concentration/ not to exceed

C = ceiling limit for a 15-minute sample

[ ] = proposed TLV on the ACGIH Notice of Intended Changes

A2 = suspected human carcinogen

**Table 2**  
**Personal Breathing Zone Air Samples for Metals**  
**HETA 94-0273-2556**  
**January 11, 1995**

Job Task / Location (floor)	Sample time (military)	Sample Vol. (liters)	As	Be	Cd	Pb	TiO <sup>2</sup>
			µg/m <sup>3</sup>	µg/m <sup>3</sup>	µg/m <sup>3</sup>	µg/m <sup>3</sup>	µg/m <sup>3</sup>
boiler drain/ 1st-7th	0710 - 1701	1182	ND	ND	ND	ND	2.3
boiler drain/ 1st-7th	0709 - 1704	1190	Trace	ND	ND	ND	4.4
boiler drain/ 5th	0710 - 1706	1192	ND	ND	ND	ND	7.6
boiler drain/ 6th	0706 - 1707	1202	Trace	ND	ND	ND	5.7
boiler drain/ 7th	0704 - 1703	1198	ND	ND	ND	ND	5.3
boiler drain/ 8th	0705 - 1651	1172	30.7	0.39	0.75	11.9	227
soot blower/ 6-8th	0714 - 1701	1174	ND	ND	ND	ND	4.9
soot blower/ 6-8th	0723 - 1650	1134	ND	ND	ND	ND	5.3
soot blower/ 8th	0713 - 1655	1164	ND	ND	ND	ND	2.6
soot blower/ 8th	0710 - 1658	1176	ND	ND	ND	ND	6.1
soot blower/ 8th	0708 - 1703	1190	10.9	0.14	ND	Trace	86.8
soot blower/ 8th	0716 - 1653	1154	Trace	ND	ND	ND	6.7
soot blower/ 8th	0716 - 1657	1162	ND	ND	ND	ND	4.7
soot blower/ 8th	0714 - 1656	1164	ND	Trace	ND	ND	7.2
soot blower/ 8th	0710 - 1652	1164	ND	ND	ND	ND	4.9
soot blower/ 8th	0715 - 1706	1182	3.4	Trace	2.5	5.1	32.6
soot blower/ 8th	0712 - 1655	1166	Trace	ND	ND	ND	4.0
soot blower/ 8th	0712 - 1657	1170	Trace	ND	ND	ND	4.3
soot blower/ 10th	0715 - 1700	1170	ND	ND	ND	ND	5.9
combust. line/ 4-6th	0707 - 1700	1186	Trace	ND	ND	ND	5.9
combust. line/ 4-6th	0711 - 1701	1180	ND	ND	ND	ND	6.2
combust. line/4-6th	0720 - 1703	1166	ND	ND	ND	Trace	7.6
various/BM & 5-7th	0713 - 1654	1162	ND	ND	ND	ND	5.2
<b>**Evaluation Criteria</b>		NIOSH REL	LFC/ 2 C	LFC/ .5	LFC	100	LFC
	<b>*** Adjusted</b>	OSHA PEL	5.6	1.1	2.8	28	8,400
	<b>*** Adjusted</b>	ACGIH TLV	5.6, A1	1.1, A2	5.6, A2	[28, A3]	5,600
		OSHA PEL	10	2	5	50	15,000
		ACGIH TLV	10, A1	2, A2	10, A2	[50, A3]	10,000

\* Indicates employees worked in lead area

\*\* Evaluation criteria are listed for 8-hour time weighted averages, unless other wise noted

\*\*\* Adjusted occupational exposure limit using the Breif and Scala model<sup>18</sup>

µg/m<sup>3</sup> = micrograms per cubic meter

ND = not detected

Trace = concentration between MDC and MQC

BM = basement

A1 = confirmed human carcinogen

A3 = animal carcinogen

mg/m<sup>3</sup> = milligrams per cubic meter

LFC/ = lowest feasible concentration/ not to exceed

C = ceiling limit for a 15-minute sample

[ ] = proposed TLV on the ACGIH Notice of Intended Changes

A2 = suspected human carcinogen

**Table 3**  
**Bulk Samples**  
**Bruce Mansfield Power Station**  
**Shippingport, Pennsylvania**  
**HETA 94-0273-2556**  
**January 10, 1995**

	Location							
	elec. conduit 9th floor C 12 pillar	rafter 8th floor south side bl	rafter 5th floor D 17 pillar	soot blower 12th floor D 17 pillar	soot blower 11th floor D 16 pillar	soot blower 10th floor east side bl	inside bl 8th floor west side bl	
<b>Metals*</b>	<i>settled dust</i>	<i>settled dust</i>	<i>settled dust</i>	<i>settled dust</i>	<i>settled dust</i>	<i>settled dust</i>	<i>fly ash</i>	<i>coal sample</i>
Aluminum	25,000.0	20,000.0	17,000.0	23,000.0	24,000.0	22,000.0	11,000.0	3,600.0
<b>Arsenic</b>	<b>120.0</b>	<b>99.0</b>	<b>Trace</b>	<b>120.0</b>	<b>98.0</b>	<b>110.0</b>	<b>Trace</b>	<b>ND</b>
Barium	180.0	140.0	99.0	190.0	170.0	150.0	140.0	53.0
<b>Beryllium</b>	<b>2.3</b>	<b>2.1</b>	<b>1.5</b>	<b>2.0</b>	<b>1.9</b>	<b>1.9</b>	<b>Trace</b>	<b>Trace</b>
Calcium	14,000.0	13,000.0	8,200.0	11,000.0	12,000.0	13,000.0	11,000.0	650.0
<b>Cadmium</b>	<b>ND</b>	<b>22.0</b>	<b>22.0</b>	<b>3.8</b>	<b>5.1</b>	<b>Trace</b>	<b>ND</b>	<b>ND</b>
Cobalt	13.0	Trace	Trace	12.0	13.0	12.0	Trace	ND
Chromium	150.0	180.0	81.0	260.0	400.0	190.0	86.0	ND
Copper	42.0	110.0	24.0	79.0	89.0	50.0	40.0	Trace
Iron	67,000.0	67,000.0	50,000.0	71,000.0	87,000.0	64,000.0	94,000.0	3,500.0
Lithium	38.0	29.0	21.0	23.0	24.0	33.0	62.0	Trace
Magnesium	2,500.0	1,900.0	1,300.0	1,600.0	1,700.0	2,000.0	620.0	260.0
Manganese	190.0	130.0	120.0	170.0	200.0	150.0	94.0	13.0
Molybdenum	11.0	13.0	6.6	40.0	96.0	17.0	6.3	ND
Nickel	43.0	51.0	31.0	95.0	110.0	50.0	26.0	ND
<b>Lead</b>	<b>85.0</b>	<b>52.0</b>	<b>Trace</b>	<b>530.0</b>	<b>150.0</b>	<b>48.0</b>	<b>Trace</b>	<b>ND</b>
Phosphorous	730.0	760.0	350.0	780.0	780.0	840.0	330.0	ND
Platinum	Trace	Trace	Trace	Trace	Trace	Trace	Trace	ND
Selenium	Trace	Trace	Trace	Trace	Trace	Trace	Trace	ND
Silver	ND	ND	ND	ND	ND	ND	ND	ND
Sodium	1,300.0	1,000.0	800.0	800.0	840.0	1,200.0	1,300.0	390.0
Tellurium	ND	ND	ND	ND	ND	ND	ND	ND
Thallium	ND	ND	ND	ND	ND	ND	ND	ND
Titanium	820.0	640.0	560.0	700.0	710.0	670.0	460.0	390.0
Vanadium	92.0	87.0	45.0	88.0	92.0	94.0	61.0	Trace
Yttrium	15.0	13.0	8.6	15.0	15.0	14.0	9.8	3.6
Zinc	1,500.0	170.0	130.0	570.0	680.0	360.0	38.0	Trace
Zirconium	30.0	26.0	20.0	42.0	31.0	28.0	15.0	7.3

\* All quantities presented in this table are in micrograms per gram of sample ( $\mu\text{g/g}$ )  
bl = boiler    Trace = quantity between LOD and LOQ    ND = not detected



**Table 4**  
**Hand Wipe Samples**  
**Bruce Mansfield Power Station**  
**Shippingport, Pennsylvania**  
**HETA 94-0273-2556**  
**January 10, 1995**

Job Task / Location (floor)	Soot blower 15th floor	Soot blower 8th floor	Soot blower 8-11th floor	Soot blower various	Soot blower 15th floor
*Wash hands	No	No	Yes	NA	No
Arsenic	8.6	2.5	6.1	6.0	22.0
Beryllium	0.05	ND	Trace	ND	0.1
Cadmium	3.7	0.9	2.9	3.6	13.0
Lead	18.0	4.4	7.0	9.4	21.0
Titanium	18.0	4.0	14.0	11.0	32.0

**Table 5**  
**Hand Wipe Samples**  
**Bruce Mansfield Power Station**  
**Shippingport, Pennsylvania**  
**HETA 94-0273-2556**  
**January 11, 1995**

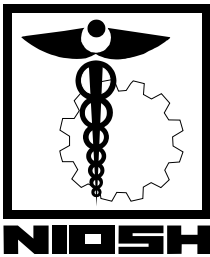
Job Task / Location (floor)	Soot blower 8th floor	Soot blower 8th floor	Soot blower 8th floor	Boiler drain 6th floor	Soot blower 8th floor	Various 5-8th floor
*Wash hands	Yes	No	No	Yes	No	No
Arsenic	6.3	21.0	9.6	3.9	41.0	7.5
Beryllium	ND	0.1	Trace	ND	0.3	Trace
Cadmium	1.8	25.0	21.0	5.8	23.0	3.9
Lead	5.6	22.0	17.0	15.0	35.0	7.8
Titanium	7.7	42.0	21.0	5.8	89.0	17.0

All quantities presented in the above tables are in micrograms per wipe ( $\mu\text{g/wipe}$ )

\*Indicates if employees washed hands before hand wipe

NA = not available  
 ND = not detected  
 Trace = quantity between LOD and LOQ





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