EVALUATION OF THE POTENTIAL MIGRATION OF HEXAVALENT CHROMIUM AND MANGANESE DURING HOT WORK ACTIVITIES AT A FOSSIL FUEL GENERATION FACILITY

by

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Abstract

Hexavalent Chromium, also known as Cr(VI), is a known carcinogenic fume given off when welding or cutting is performed on stainless steel. In addition, other heavy metals are released through these processes; including lead, manganese (Mn), and molybdenum. In March 2006 the Occupational Safety and Health Administration (OSHA) implemented a new Cr(VI) standard, lowering the Permissible Exposure Limit (PEL) from 52 $\mu g/m^3$ to 5 $\mu g/m^3$.

In recent years, an emphasis has been made on an additional metal fume, manganese. Recent studies have shown that individuals exposed to high levels of Mn can develop neurological problems. The American Conference of Governmental Industrial Hygienists (ACGIH) proposed a change of the Mn Threshold Limit Value (TLV) in the 2010 edition of the ACGIH *TLVs and BEIs* from 0.2 mg/m^3 to 0.02 mg/m^3.

This study evaluated the exposure to Cr(VI) and Mn associated with shielded metal arc welding (SMAW) on stainless steel and the migration of Cr(VI) and Mn in a fossil fuel generation facility. The facility is composed of eight different maintenance crews, which are responsible for the maintenance of a specific area of the facility. The crew evaluated is composed of twelve mechanics and works primarily with stainless steel material.

Results showed detectable concentrations that were below the occupational exposure limit of Cr(VI) in two of the personal breathing zone samples and detectable concentrations below the occupational exposure limit in one of the general area trials 10 feet away from the work area. Mn concentrations below the occupational exposure limit were detected in all four trials in the personal breathing zone samples and general area samples 10 feet away from the work area. None of the general area samples collected in the hallway or breakroom detected a measurable concentration of Cr(VI) or Mn. Wipe samples collected showed concentrations of Mn in all of the trials but Cr(VI) was not observed in any of the wipe samples.

While the study showed a lack of migration of Cr(VI) and Mn through the area air samples, Mn was detected in all of the breakroom wipe samples. It is postulated that migration occurred through the transfer of particles from the employees clothing to the breakroom. It is suggested the welders do utilize local exhaust ventilation and practice good hygiene. Welders are encouraged to wash their work clothes frequently, as well.

Keywords: Hexavalent Chromium, Manganese, Industrial Hygiene, Stainless Steel

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The biggest thanks needs to be given to the employees who wore the sampling equipment during their shifts. I would also like to thank the facilities Plant Manager for allowing me to conduct this study. Lastly, I would like to thank Todd Wulf for his assistance and motivation in completing this study.

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1. Introduction

1.1. Regulatory Information

Employee health is a primary concern for employers. Research provides groups such as the American Conference of Governmental Industrial Hygienists (ACGIH), National Institute for Occupational Safety and Health (NIOSH), and the Occupational Health Administration (OSHA) with information on toxicity to evaluate occupational exposure limits (OELs). As the toxicity of certain materials is identified, these groups determine an acceptable occupational exposure limit for the contaminant. The Occupational Safety and Health Administration must pass legislation to lower the regulatory permissible exposure limit. Difficulties associated with passing legislation to lower the PEL make utilizing the ACGIH or NIOSH occupational exposure limits a safer choice for employees.

In 2006, OSHA lowered the PEL for hexavalent chromium (Cr(VI)) from 52 $\mu g/m^3$ to 5 $\mu g/m^3$. Because of the known carcinogenic properties of Cr(VI), it is vital that employers evaluate exposure levels to ensure the precautions they are taking are adequate. In addition to the Cr(VI) PEL being lowered, ACGIH also lowered the threshold limit value (TLV) for Mn in 2011. The new TLV was lowered to 0.1 mg/m^3 inhalable fraction and 0.02 mg/m^3 respirable fraction from 0.2 mg/m^3. The PEL of 5 mg/m^3 has yet to be lowered by OSHA. Proactive employers are currently monitoring employees during welding activities to determine effective ways to control exposure to Mn.

The main exposure route for Cr(VI) and Mn is inhalation. When individuals perform welding, cutting, or grinding on stainless steel material the heavy metal fumes become airborne. These fumes may then be inhaled by an employee if proper precautions are not taken. The chronic inhalation of heavy metals, such as Cr(VI) or Mn, can potentially lead to respiratory and/or central nervous system effects.

1.2. Objectives

With new emphasis on certain heavy metals given off during Hot Work activities employers need to ensure additional employees are not being exposed to these heavy metals through migration. The data gathered during this study will determine if employees that are not directly involved with the Hot Work activities are being exposed to heavy metals released and dispersed during Hot Work. The primary objective of this study was to evaluate the potential for welding fume migration from the welding area to general plant work areas and the breakroom. In addition to the primary objective, welder breathing zone exposures will be assessed to determine the exposure level at the work area.

1.3. Hypotheses

There were twelve hypotheses tested during this study:

Null Hypothesis #1	Welders will be exposed to levels of Cr(VI) below the OELs.
Research Hypothesis #1	Welders will be exposed to levels of Cr(VI) at or above the OELs.
Null Hypothesis #2	Hexavalent chromium will not be detected in area samples ten feet away from the work area.
Research Hypothesis #2	Hexavalent chromium will be detected in area air samples ten feet away from the work area.
Null Hypothesis #3	Hexavalent chromium will not be detected in area samples in the hallway leading to the crew breakroom.
Research Hypothesis #3	Hexavalent chromium will be detected in area samples in the hallway leading to the crew breakroom.
Null Hypothesis #4	Hexavalent chromium will not be detected in area samples in the crew breakroom.
Research Hypothesis #4	Hexavalent chromium will be detected in area samples in the crew breakroom.

Null Hypothesis #5 Hexavalent chromium will not be detected in wipe samples on the table near where the welding employees take breaks.

Research Hypothesis #5 Hexavalent chromium will be detected in wipe samples on the table near where the welding employees take breaks.

Null Hypothesis #6 Hexavalent chromium will not be detected in wipe samples on a table away from where the welding employees take breaks.

Research Hypothesis #6 Hexavalent chromium will be detected in wipe samples on a table away from where the welding employees take breaks.

Null Hypothesis #7 Welders will be exposed to levels of Mn below the OELs.

Research Hypothesis #7 Welders will be exposed to levels of Mn at or above the OELs.

Null Hypothesis #8 Manganese will not be detected in area samples ten feet away from the work area.

Research Hypothesis #8 Manganese will be detected in area samples ten feet away from the work area.

Null Hypothesis #9 Manganese will not be detected in area samples in the hallway leading to the crew breakroom.

Research Hypothesis #9 Manganese will be detected in area samples in the hallway leading to the crew breakroom.

Null Hypothesis #10 Manganese will not be detected in area samples in the crew breakroom.

Research Hypothesis #10 Manganese will be detected in area samples in the crew breakroom.

Null Hypothesis #11 Manganese will not be detected in wipe samples on the table near where the welding employees take breaks.

Research Hypothesis #11 Manganese will be detected in wipe samples on the table near where the welding employees take breaks.

Null Hypothesis #12 Manganese will not be detected in wipe samples on a table away from where the welding employees take breaks.

Research Hypothesis #12 Manganese will be detected in wipe samples on a table away from where the welding employees take breaks.

2. Background

2.1. Facility Overview

The study took place at a fossil fuel generation facility. The facility burns pulverized coal to turn water into steam. The steam then turns a turbine and generator, creating energy. If coal was made up of pure carbon the only byproduct given off would be carbon dioxide. Since coal is not pure carbon, and often contains other minerals, the combustion releases contaminants that need to be removed prior to discharge into the ambient environment. The treatment of these gaseous byproducts occurs in scrubber vessels where the gas is sprayed with water and additional chemicals. Figure 1 depicts the flow of gaseous byproduct.

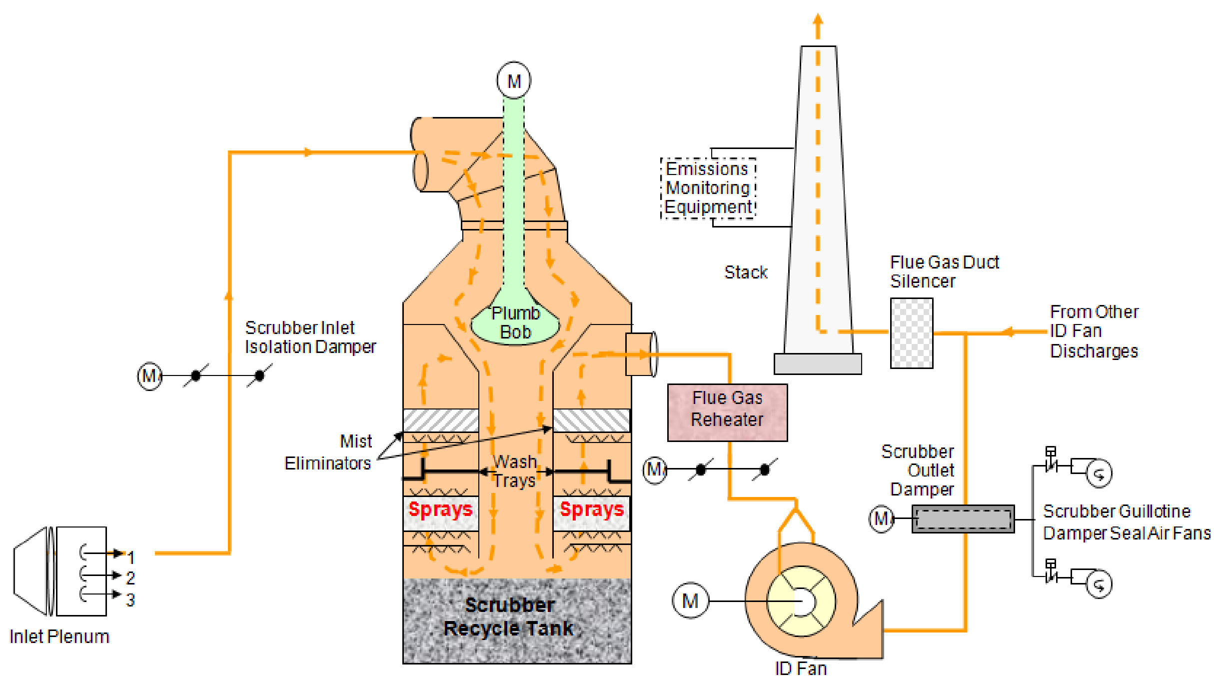

Figure 1: Operational Depiction of a Scrubber Vessel

Due to the corrosive nature of the materials in the scrubber vessels the vessels are often composed of stainless steel. The use of stainless steel prolongs the life of equipment but introduces additional hazards when maintenance is required on these pieces of equipment.

Maintenance on these vessels is required in order to continue to provide safe, clean, and reliable energy to the American public.

2.2. Work Conditions

Employees monitored at the fossil fuel generation facility are tasked with ensuring the equipment at the facility is functioning properly. A select few of these employees are certified to weld on stainless steel material. Rarely is there a situation when the employee will weld on stainless steel for the duration of the ten-hour shift. Whenever an employee welds on carbon steel or stainless steel, it is company policy to wear a half-mask air-purifying respirator with P100 filters at a minimum. Employees also have access to supplied air fittings for their respirator to provide supplied air to them. Portable local exhaust ventilation units are available for use but during the study the employees chose to not utilize them because the areas where they were working had natural ventilation. Previous air monitoring has confirmed that employees do not need to utilize local exhaust ventilation and respiratory protection. Historical welding fume sample results have revealed exposures low enough to allow the use of only a half-masked air purifying respirator.

During the employees' shifts, they are allotted three breaks. Two of the breaks are 15 minutes in duration and the third break is their meal break, which is 30 minutes in duration. Washing facilities are provided to employees but typically employees will only shower and change clothes at the end of their shift. Each employee has access to laundry facilities onsite to minimize the amount of contaminant an employee can potentially bring home. Employees that perform welding utilize the onsite laundry facilities to ensure contaminants from work are not being transported to their homes.

2.3. Stainless Steel

Stainless steel is a widely used product due to its ability to resist corrosion. For a material to be considered stainless is must have a least 11% chromium base (Lai, 2012). Depending on the category of the stainless steel, the chromium levels will vary for different applications. In order to resist corrosion, other alloys such as Mn, molybdenum, and nickel are utilized. The combination of numerous elements at various concentrations creates different categories of stainless steel material. Certain types of stainless steel are used in different applications where more or less corrosion resistance may be required. The facility evaluated in this study mainly utilizes two forms of stainless steel in the scrubbers.

2.3.1. 317L Stainless

The first type of stainless steel that is found at the facility is 317L stainless. Improved corrosion resistance is the main difference in 317L versus 316L. Formability and weldability make 317L an obvious choice for the application it is used in at the site. Table 1 below displays the chemical composition of 317L stainless.

Table 1: Chemical Composition 317L, %

	317L Min	317L Max
Nickel	11.0	15.00
Chromium	18.0	20.00
Molybdenum	3.0	4.00
Manganese	-	2.00
Silicon	-	0.75
Carbon	-	0.03
Nitrogen	-	0.10
Sulfur	-	0.03
Phosphorus	-	0.045
Iron	Balance	

(Rolled Alloys, 2013)

The chemical composition is important when evaluating occupational exposures. The higher the material's metal content, the higher the potential occupational exposure to that metal.

2.3.2. 2205 Stainless

The second type of stainless steel the facility uses is 2205 stainless. Recently, the facility has been replacing all of the 317L stainless with the 2205 stainless. Chromium content in 2205 is higher than 317L, which resists corrosion better and has a higher resistance to chloride stress corrosion. The formability of 2205 is not as good as 317L, but for the application it is used for at the facility formability is not an issue. Table 2 lists the chemical composition of 2205 stainless.

Table 2: Chemical Composition 2205, %

	2205 Min	2205 Max
Nickel	4.50	6.50
Chromium	22.00	23.00
Molybdenum	3.00	3.50
Manganese	-	2.00
Silicon	-	1.00
Carbon	-	0.03
Nitrogen	0.14	0.20
Sulfur	-	0.02
Phosphorus	-	0.03
Iron	Balance	-

(Rolled Alloys, 2013)

The larger amount of chromium in 2205 stainless makes it less susceptible to corrosion. Areas where 2205 stainless are utilized are consistently exposed to corrosion, which requires the higher amount of corrosion-resistance desirable.

2.4. Welding

The constant operation of equipment in the fossil fuel generation facility requires equipment to undergo regular maintenance. Due to the abrasive and corrosive nature of the material moving through the scrubbers, the equipment and piping is cut out and replaced on a daily basis at the facility. In order to replace the equipment and piping, the employees must weld the equipment into place.

Welding is the joining of metals by applying heat, with a filler metal having a high melting point (Welding, 2009). Two types of welding exist, fusion welding and pressure welding. Fusion welding utilizes heat to join the two metal surfaces and pressure welding requires heat and pressure to complete the weld. Fusion welding is composed of electric arc, gas, and thermite welding. Electric arc welding is commonly the most widely-used form of fusion welding used in the industry (Controlling Hazardous Fume and Gases during Welding, 2013). Arc welding uses an electrode, either a consumable wire or rod or a non-consumable carbon or tungsten rod, which carries the electrical current to the surface. The consumable electrode will carry the current to the surface metal and provide filler material whereas non-consumable electrodes carry the current and the filler material is provided by a different wire or rod. Arc welding utilizes shielding gases and slag coverings to protect the weld from oxidation. The shield gas protects the weld from nitrogen and oxygen while the weld pool is being formed (F.C., 2011). Four main types of arc welding exist. Flux core arc welding (FCAW) utilizes a filler metal electrode and a flux shield. With shielded metal arc welding (SMAW), the electrode provides both the flux and filler material. Gas metal arc welding (GMAW or MIG) utilizes a separate gas and a consumable electrode. Finally, gas tungsten arc welding (GTAW or TIG) utilizes a separate gas source and a non-consumable electrode (Controlling Hazardous Fume and Gases during Welding, 2013). Pictured below are two individuals performing shielded metal arc welding.

Figure 2: Individuals Performing SMAW in a Scrubber Vessel

2.4.1. Shielded Metal Arc Welding (SMAW)

The majority of the welding that occurs at the facility is SMAW because of the limited amount of equipment needed and the portability of the equipment. Shielded metal arc welding is a welding process that uses a flux-covered consumable electrode to create a weld. A shield gas is produced by the consumption of the flux-covered electrode and does not require the use of compressed gas for a shield gas. Since a shield gas is not required for SMAW, additional hoses are not required, making SMAW a preferred welding process for welders. An additional benefit that SMAW provides is the ease of welding. A large amount of welding that occurs at the facility occurs on thicker material. When utilizing thicker material, exact precision is not needed, thus making SMAW quicker and easier than other welding methods. Thicker material also allows less experienced welders perform SMAW. Shielded Metal Arc Welding can also be performed in confined areas and on vertical or overhead surfaces. For a facility that has over 1,600 identified confined spaces, ease of welding is a necessity, making SMAW a logical choice.

To perform SMAW, welders need a power source, a welding machine, and a consumable electrode. Electrical current is run through the electrode and the grounded material creating the weld. First, the welder must initiate a spark at the weld to ensure the material is adequately grounded. If the material is not adequately grounded the welder must reground the material prior to welding or the welder will not achieve the desired weld. Once an adequate ground is achieved, the welder lays down a line of filler joining the two pieces of material. A depiction of SMAW is shown in Figure 3 below.

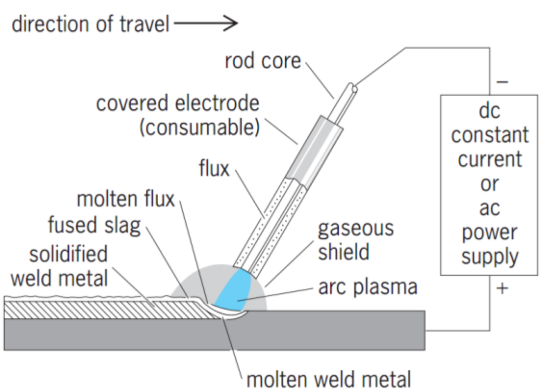

Figure 3: SMAW Process (Shielded metal-arc welding, 2011)

2.5.Contamination Migration Study conducted by NIOSH

In 1995, NIOSH conducted a study comparing the concentration of contaminants that individuals encounter at work with levels of those contaminants found in their homes and cars (Services, 1995). Monitoring was conducted at the homes of these same individuals to determine if the levels of the contaminant were higher at their homes versus a control home. Lead dust was measured in the homes of smelter workers in Tennessee. The average concentration of lead dust in the homes of the smelter workers was found to be 1,240 ppm versus an average concentration of 404 ppm in the control homes (Services, 1995). Another study evaluated the levels of arsenic in the homes of workers exposed to arsenic in Hawaii. Levels of arsenic in the homes of these employees ranged from 5.2 to 1,080 ppm compared to 1.1-31 ppm in the control homes (Services, 1995). Mercury levels near the washer and dryers of mercury miners were observed to be 5-50 $\mu g/m^3$. The NIOSH recommended exposure limit of mercury is 50 $\mu g/m^3$ for a 10-hour shift. Reports of health effects and deaths from contaminants brought home from the work place have been reported in 28 countries and 36 states (Services, 1995). Research concluded that employees of the companies evaluated in the study were transporting the contaminants home on their clothes and skin. It was determined by NIOSH that better educational programs on preventing the migration of contaminants is needed. Training employees on good hygiene practices and the hazards associated with the contaminants they work with can easily prevent the contamination of homes.

2.6.Asbestos Migration Studies

Asbestos migration will also occur through the air. Since asbestos is a fiber, it is possible for the fiber to migrate miles via the air (ATSDR, 2001). Manufacturing facilities and mines that process minerals that contain forms of asbestos cause the fibers to become airborne. These airborne fibers may be inhaled by individuals who live around the area (ATSDR, 2001).

Studies conducted on asbestos migration have provided information on home contamination. Levels of asbestos transferred to the homes resulted in asbestos-related illnesses in individuals who did not work in an asbestos-related field. Migration associated with asbestos has resulted in regulations that require strict decontamination and containment procedures to ensure asbestos migration does not occur.

2.7. Hexavalent Chromium (Cr(VI))

Since 1975, NIOSH has recognized Cr(VI) as a lung carcinogen. Even though NIOSH had recognized Cr(VI) as a lung carcinogen, OSHA did not start regulating the exposure until 2001 (Reduce Metal-Induced Lung Cancer (Hexavalent Chromium), 2008). Chromium (Cr) is a naturally-occurring metallic element that exists in different valence states. Trivalent chromium (Cr(III)) and hexavalent chromium (Cr(VI)) are two of the most common valance states of chromium that are found in industry. Rate of transfer across cell membranes is the major difference between Cr(III) and Cr(VI). Trivalent chromium is much less able to cross cell membranes, whereas Cr(VI) can readily cross cell membranes (ATSDR, 2012). At the facility, employees are potentially exposed to Cr(VI) via inhalation of airborne concentrations when welding is conducted on stainless steel material or when hard surfacing with a high-chromium-content electrode.

Particle size plays a key role in the inhalation exposure of Cr(VI). Each region of the respiratory system functions differently in terms of protecting the body. Particles of different sizes deposit in different areas of the respiratory system. Large particles, 5µm or larger, are inhaled and deposited primarily in the nasopharyngeal region also known as the head airways region. Finer particles that are between 5µm and 1 µm pass the nasopharyngeal region and deposit primarily in the tracheobronchiolar region of the respiratory system. Particles that are smaller than 1 µm pass both the nasopharyngeal and tracheobronchiolar region depositing on the alveoli. Most welding fumes are smaller than 1µm causing them to reach the alveoli in the lungs. Hexavalent chromium diffuses through the alveoli entering the epithelial cells. Within the epithelial cells, Cr(VI) is reduced to Cr(V) by nicotinamide adenine dinucleotide/ nicotinamide adenine dinucleotide phosphate (NADH/NADPH) forming oxygen radicals that cause damage to DNA. Damage to DNA is a direct result of the oxidative stress caused by the reduction of Cr(VI) to Cr(V) contributing to the development of cancer (Zelicoff, Thomas, & T., 1998).

The known carcinogenic nature of Cr(VI) caused OSHA to reevaluate the occupational exposure limit. Prior to 2006, the PEL for Cr(VI) was 52 $\mu g/m^3$. In 2006, OSHA revised the PEL and implemented enforcement of the hexavalent chromium standard 1910.1026. OSHA lowered the PEL to 5 $\mu g/m^3$ with an action limit of 2.5 $\mu g/m^3$. Specific sections of 1910.1026 also require additional action by employers. Employees that spend 30 days or more at the action level must be enrolled in a medical surveillance program. This required employers to monitor and track employee exposure more closely, resulting in better protection for the work force.

2.7.1. Additional Toxicological Effects

In addition to the carcinogenic nature of Cr(VI), non-cancer toxicological effects exist from Cr(VI) exposure. A study completed by the Agency for Toxic Substances and Disease Registry (ATSDR), evaluated the different toxicological effect of individuals exposed to various doses of Cr(III) and Cr(VI) (ATSDR, 2012). Several different systemic effects were researched during the study but, the major systems affected from chromium exposure were respiratory and gastrointestinal complications.

2.7.1.1. Respiratory Effects

The 2012 Toxicological Profile for Chromium, conducted by the ATSDR showed individuals acutely exposed to Cr(VI) might develop asthma and other signs of respiratory distress. Individuals who are chronically exposed to high levels of Cr(VI) often develop symptoms of sneezing, labored breathing, and a choking sensation when working around chromium fumes (ATSDR, 2012). Many individuals chronically exposed to Cr(VI) also report nasal septum perforation.

2.7.1.2. Gastrointestinal Effects

Gastrointestinal effects have been associated with occupational exposures, resulting in abdominal or substernal pain (ATSDR, 2012). Gastrointestinal symptoms individuals have reported from Cr(VI) include duodenal ulcers, gastritis, stomach cramps, and frequent indigestion. These symptoms can be the result of inhilation of chromium particles or the swallowing of chromate dust. Gastrointestinal effects occur when indivduals breathe Cr(VI) in through their mouth and then swallow the gastrointestinal mucosa that contains the Cr(VI) or via hand-to-mouth activities.

2.8. Manganese (Mn)

Manganese occurs naturally in rocks and soil. At the fossil fuel generation facility, Mn can be found in the steel used at the site. Steel production facilities utilize Mn to add hardness, stiffness, and strength to the steel. Individuals are exposed to Mn when welding is performed on steel that contains Mn and when using electrodes containing Mn. Fumes that contain certain amounts of Mn can be inhaled during the welding process exposing individuals to high levels of Manganese.

2.8.1. Manganese Neurological Effects

Human bodies require small amounts of Mn to manufacture enzymes for the metabolism of proteins and fats. Individuals exposed to excessive amounts of Mn can develop manganism, an irreversible brain disease (Toxic Substances Portal - Manganese, 2012). Individuals who suffer from manganism often display many of the symptoms of Parkinson's disease resulting in terms such as "Parkinsonism-like disease." Symptoms of manganism are progressive and can include altered gait, fine tremor, and sometimes psychological disturbances (hallucination and psychosis). These symptoms typically occur in individuals who were exposed to high levels of

Mn over a period of several years but some individuals may start showing signs one to three months after exposure. Early symptoms of manganism have been described as halting speech, dull and emotionless facial expression, and slow and clumsy movement of limbs. Once the disease starts to progress, walking becomes difficult, muscles become hypertonic, and voluntary movements are accompanied by tremor (Toxic Substances Portal - Manganese, 2012). Studies have shown that even after an individual stops being chronically exposed to Mn, symptoms continue to worsen.

2.8.2. Manganese Respiratory Effects

Acute inhalation exposure can result in lung inflammation and irritation. Inflammation is caused by the infiltration of manganese into macrophages and leukocytes, which phagocytize (eat) the Mn particles (Williams & McClure, 2012). Inhalation of Mn usually leads to an increase of coughing and bronchitis and can lead to minor lung tissue damage causing minor decreases in lung function (Toxic Substances Portal - Manganese, 2012). Damage caused by the inhalation of Mn increases the chances that Mn-exposed workers will contract pneumonitis and pneumonia. These effects primarily occur in workers who are exposed to high concentrations of Mn dust in the workplace (Toxic Substances Portal - Manganese, 2012).

2.8.3. Reproductive Effects

Males displaying signs of manganism commonly experience impotence and loss of libido. These effects potentially lead to a reduced reproductive success in men. Workers exposed to Mn dust for 1-19 years have experienced impaired fertility at exposure levels lower than the levels required to contract manganism. Impaired sexual function can be an early indication of Mn toxicity in males. There have been no observed effects on the fertility of women from Mn toxicity (Toxic Substances Portal - Manganese, 2012).

2.8.4. Developmental Effects

Evidence suggests that children exposed to high levels of Mn from environmental sources may develop adverse developmental effects, particularly the neurological effects previously discussed. Research has shown that children exposed to Mn over a long period of time will eventually develop one or more symptoms, including cognitive impairment, diminished memory, attention deficit, motor impairment, aggressiveness, and/or hyperactivity (Toxic Substances Portal - Manganese, 2012). It is unclear if Mn exposure alone causes the development of these symptoms or if other factors in conjunction with the presence of Mn are required.

2.8.5. Additional Manganese Information

Unlike Cr(VI), OSHA has not yet put an emphasis on Mn. The American Conference of Governmental Industrial Hygienists published an intent to change the TLV for Mn in 2010. In 2011, the TLV was changed to a limit of 0.1 mg/m^3 for the inhalable fraction. NIOSH and OSHA have not yet modified occupational exposure limits to reflect the ACGIH change. Both organizations recognize the brain and central nervous system as target organs but NIOSH has kept the 1 mg/m^3 TWA and OSHA has kept the 5 mg/m^3 PEL in place. Information on the hazards associated with Mn is well documented and proactive employers have realized the change in the TLV and are preparing for a change in the PEL to be ahead of other companies within the industry.

2.8.6. Manganese Case Studies

A study was conducted involving five surviving workers that were chronically exposed to Mn in a ferroalloy plant (Toxic Substances Portal - Manganese, 2012). These individuals were exposed for 3 to 13 years and examined 9 to 10 years after the exposure. Original evaluation showed Mn levels higher than normal and over time the Mn levels slowly declined to a normal level. Even though the Mn levels were declining, symptoms of manganism still progressed (Toxic Substances Portal - Manganese, 2012).

In 1990, Iregren conducted a study on 30 male workers from two different Mn foundries who were exposed to low concentrations of Mn. Neurobehavioral tests were used to evaluate the individuals' reaction times, finger tapping, and other simple neurobehavioral skills. Workers that participated in the study had below average scores on a number of the tests when compared to individuals with no occupations exposure to Mn (Toxic Substances Portal - Manganese, 2012).

3. Methodology

Historical exposure monitoring at the plant consisted of personal breathing zone (PBZ) sampling. In this study, PBZ sampling was conducted as well as area sampling. The purpose of the area sampling was to evaluate the potential airborne migration of hexavalent chromium and Mn welding fumes from the direct welding site to neighboring locations, including the employee breakroom. Typically, employers are concerned with personal exposure and the possibility of employee exposure in the work area. This study added a third element to the concern, the migration of hexavalent chromium and Mn. Four separate trials were conducted to determine if migration of hexavalent chromium or Mn occurred. Each trial consisted of one PBZ sample, three general area (GA) samples, and four wipe samples to evaluate the potential migration of Cr(VI) or Mn. Employees do not work at one single location during the day. Figure 4 below illustrates the sampling locations for each trail.

Figure 4: Trial Location Diagram

3.1.Air Sampling Methods

To evaluate the exposure and compare that exposure to the potential migration of hexavalent chromium and Mn, two sample types where required; these included personal breathing zone and general area samples. Four trials were conducted utilizing both personal breathing zone and general area samples.

Two personal breathing zone (PBZ) samples were conducted to assess potential breathing zone exposures of Cr(VI) and Mn of workers that perform Hot Work activities involving stainless steel. PBZ samples were collected following the OSHA sampling method ID 215 and NIOSH Method 7300. MSA Escort ELF personal sampling pumps were used with a 37-mm

Polyvinyl Chloride filter (5-µm pore size) contained in a 2-piece polystyrene cassette to sample for Cr(VI) and a 37-mm Cellulose Ester Membrane (0.8-µm pore size) contained in a 2-piece polystyrene cassette was used to sample for Mn. Each pump was calibrated at 2 L/min using a Gilian Gilibrator 2 primary-flow calibrator prior to and immediately after sampling. The 2-piece cassette was placed in the breathing zone, roughly, 6 inches from the individual's nose and mouth to simulate the individual's PBZ. Prior to sampling, the cap covering the inlet port of the 2-piece polystyrene cassette was removed and the cap was replaced immediately after sampling to ensure sample integrity. Analysis of all samples was conducted by ALS Laboratory in Salt Lake City, UT following protocols outlined in Hexavalent Chromium in Workplace Atmospheres, OSHA method ID 215, (Ku, 2006) and Metals by ICP, NISOH 7300 (Millson & Andrews, 2003).

Three 37-mm PVC general area (GA) samples and three 37-mm MCE general area air samples were collected to evaluate the potential for airborne migration of Cr(VI) and Mn from the work area to the crew breakroom. General area air samples were collected utilizing the same sampling pumps and media as described with PBZ sampling above. All GA sampling cassettes were placed four to five feet from the floor to simulate breathing zone height. Samples were collected in various areas of the crew breakroom and the work location. One sample area was located approximately ten feet from the work area. The second sample area was located in the hallway of the breakroom. A third sample area was located near the tables in the breakroom.

Each sample was collected for the duration of the shift. Prior to sampling, the cap on the inlet of the 2-piece polystyrene cassette was removed and the cap was replaced immediately after sampling to ensure sample integrity.

3.2.Surface Sampling Methods

Prior to any welding activities in the shop (at the beginning of shift), two sheets of 3-mil plastic were secured over the breakroom tables. One sheet was secured on the table where employees typically sit; the second was secured in a random location on a table in the breakroom. At the conclusion of welding activities, 100 cm^2 manila templates were placed on the plastic. These templates ensured an accurate surface wipe sample area. To ensure sample integrity, Nitrile gloves were worn during wipe sample collection. For sample collection, a 37 mm PVC filter (5-µm pore size) was removed from a petri dish provided by the lab. The surface was wiped using an "S" swipe technique vertically, horizontally, and then vertically again. The filter was placed back into the dish and sent to ALS for analysis following the Hexavalent Chromium in Workplace Atmospheres OSHA method ID 215 (Ku, 2006). A second sample was collected at each location using a Ghost Wipe provided by the lab to sample for Mn. Each sample was collected using the same wipe technique as previously mentioned. After the sample was collected, the wipe was placed in a test tube provided by the lab and sent to ALS for analysis following the NIOSH 7300 method (Millson & Andrews, 2003). Wipe samples for Cr(VI) and Mn were collected side by side to ensure accurate contamination was measured at each sample area.

4. Discussion of Results

Occupational exposure limits adjusted for shift duration are given for Cr(VI) and Mn in each of the applicable tables. Exposure limits were adjusted for a 10 hour shift, since that is the shift duration of the employees. To adjust the permissible exposure limit the following equation was used (Steer & Irving, 2009).

$$\text{Modified PEL} = \text{PEL} \times \frac{8\ \text{(hours)}}{T}$$

where: T = Shift duration in hours

To modify the TLV to for shift in excess of eight hours, the Brief and Scala model was utilized. A reduction factor was calculated using the following equation (Steer & Irving, 2009).

$$\text{Reduction Factor} = \frac{8\ \text{hours}}{T} \times \frac{(24 - T)}{16}$$

where: T = Shift duration in hours

Once a reduction factor is calculated utilizing the appropriate shift duration, the TLV can be calculated for the shift by multiplying the reduction factor by the TLV (Steer & Irving, 2009).

Detectable amounts of Cr(VI) and Mn were found in several of the samples. The highest concentrations of Cr(VI) and Mn were typically found in the welder's breathing zone, in close proximity to the welding source. Results for the Cr(VI) and Mn sampling are reported in sample weight and time weighted average concentrations.

Results of the sampling are shown in the following three tables. Table 3 contains the results of the Cr(VI) monitoring. Manganese results are located in Table 4. Table 5 contains the results from the wipe samples for Cr(VI) and Mn.

Table 3: Hexavalent Chromium Concentrations in Sample Weighted and Time Weighted Average Concentrations

Sample Number	Date	Sample Type	Sample Area	Modified PEL (µg/m^3)	Sample Weighted (µg/m^3)	Sample Duration (min)	TWA (µg/m^3)
PVC-001	5/10/2013	PBZ	Person	4	<0.074	400	<0.049
PVC-002	5/10/2013	GA	Hallway	4	<0.077	393	<0.050
PVC-003	5/10/2013	GA	Work Area	4	<0.074	400	<0.049
PVC-004	5/10/2013	GA	Near Desk	4	<0.077	385	<0.049
PVC-005	5/29/2013	PBZ	Person	4	4.500	500	3.750
PVC-006	5/29/2013	GA	Near Desk	4	<0.059	495	<0.049
PVC-007	5/29/2013	GA	Hallway	4	<0.062	493	<0.051
PVC-008	5/29/2013	GA	Work Area	4	0.082	515	0.070
PVC-009	5/30/2013	PBZ	Person	4	2.800	491	2.291
PVC-010	5/30/2013	GA	Near Desk	4	<0.057	508	<0.048
PVC-011	5/30/2013	GA	Hallway	4	<0.063	467	<0.049
PVC-012	5/30/2013	GA	Work Area	4	<0.058	511	<0.049
PVC-013	5/31/2013	PBZ	Person	4	<0.060	236	<0.024
PVC-014	5/31/2013	GA	Near Desk	4	<0.060	238	<0.024
PVC-015	5/31/2013	GA	Hallway	4	<0.060	238	<0.024
PVC-016	5/31/2013	GA	Work Area	4	<0.060	190	<0.019

< is less than the analytical limit of detection limit of OSHA ID 215

Table 4: Manganese Concentrations in Sample Weighted and Time Weighted Average Concentrations

Sample Number	Date	Sample Type	Sample Area	Modified PEL (mg/m^3)	Modified TLV* (mg/m^3)	Sample Weighted (mg/m^3)	Sample Duration (min)	TWA (mg/m^3)
MCE-001	5/10/2013	PBZ	Person	4	0.07	0.001600	400	0.001067
MCE-002	5/10/2013	GA	Hallway	4	0.07	<0.000047	393	<0.000031
MCE-003	5/10/2013	GA	Work Area	4	0.07	0.000220	400	0.000147
MCE-004	5/10/2013	GA	Near Desk	4	0.07	<0.000048	385	<0.000031
MCE-005	5/29/2013	PBZ	Person	4	0.07	0.000380	500	0.000317
MCE-006	5/29/2013	GA	Near Desk	4	0.07	<0.000036	495	<0.000030
MCE-007	5/29/2013	GA	Hallway	4	0.07	<0.000036	493	<0.000030
MCE-008	5/29/2013	GA	Work Area	4	0.07	0.000150	515	0.000129
MCE-009	5/30/2013	PBZ	Person	4	0.07	0.014000	491	0.011457
MCE-010	5/30/2013	GA	Near Desk	4	0.07	<0.000036	508	<0.000030
MCE-011	5/30/2013	GA	Hallway	4	0.07	<0.000037	511	<0.000032
MCE-012	5/30/2013	GA	Work Area	4	0.07	0.000090	467	0.000070
MCE-013	5/31/2013	PBZ	Person	4	0.07	0.001600	236	0.000629
MCE-014	5/31/2013	GA	Near Desk	4	0.07	<0.000076	238	<0.000030
MCE-015	5/31/2013	GA	Hallway	4	0.07	<0.000076	238	<0.000030
MCE-016	5/31/2013	GA	Work Area	4	0.07	0.000240	190	0.000076

< is less than the analytical limit of detection limit of NIOSH 7300
*** is the modified respirable fraction TLV**

Table 5: Hexavalent Chromium and Manganese Wipe Sample Concentrations

Sample Number	Date	Sample Location	Contaminant	Sample Weighted (µg/sample)	Concentration (µg/cm²)
WIPE-001	5/10/2013	Employee's Desk	Cr(VI)	<0.060	<0.0006
WIPE-002	5/10/2013	Control Desk	Cr(VI)	<0.060	<0.0006
WIPE-003	5/10/2013	Employee's Desk	Mn	0.59	0.0059
WIPE-004	5/10/2013	Control Desk	Mn	0.4	0.004
WIPE-005	5/29/2013	Employee's Desk	Mn	1.4	0.014
WIPE-006	5/29/2013	Control Desk	Mn	0.39	0.0039
WIPE-007	5/29/2013	Employee's Desk	Cr(VI)	<0.060	<0.0006
WIPE-008	5/29/2013	Control Desk	Cr(VI)	<0.060	<0.0006
WIPE-009	5/30/2013	Employee's Desk	Mn	0.34	0.0034
WIPE-010	5/30/2013	Control Desk	Mn	0.47	0.0047
WIPE-011	5/30/2013	Employee's Desk	Cr(VI)	<0.060	<0.0006
WIPE-012	5/30/2013	Control Desk	Cr(VI)	<0.060	<0.0006
WIPE-013	5/31/2013	Employee's Desk	Mn	0.92	0.0092
WIPE-014	5/31/2013	Control Desk	Mn	0.48	0.0048
WIPE-015	5/31/2013	Employee's Desk	Cr(VI)	<0.060	<0.0006
WIPE-016	5/31/2013	Control Desk	Cr(VI)	<0.060	<0.0006

< is less than the analytical limit of detection limit of OSHA ID 215 or NIOSH 7300

4.1.Hexavalent Chromium Air Sampling Results

A total of 16 Cr(VI) air samples were collected during the shielded metal arc welding process. The sample weighted concentrations of Cr(VI) ranged from <0.058 to 4.5 µg/m³ during the trials (Table 3, column 6). Sampling time ranged from 190 to 515 minutes. Concentrations varied depending on the location where the employee was performing the welding. During the first trial, the employee performed welding outside one of the scrubber vessel reheaters outdoors with natural ventilation. We hypothesize that natural ventilation in conjunction with working outside of a confined area are the reasons for not achieving a measurable concentration of Cr(VI). The three other trials all took place within the confined space of a scrubber vessel with no mechanical ventilation. Two of the trials detected measurable quantities of Cr(VI) within the employee's breathing zone and one of these trials generated a measureable quantity of Cr(VI) within ten feet of the work area (Table 3, column 6 & 8). During all four trials there was not a detectable amount of Cr(VI) in the hallway of the breakroom or the area around the table the employee sat at during breaks and meal time.

Data reported from the lab is reported in sample weighted concentrations. Exposures that are represented in sample weighted concentrations only take into account the duration of sampling. If employees are not exposed to a contaminant for the remainder of the shift, a more accurate means to express exposure is by calculating a time weighted average. The following equation was utilized to achieve the time weighted average (1910.1000, 2006).

$$TWA = \frac{C_1 T_1}{T_x}$$

where:

C = concentration of contaminant
T = time period during which concentration was measured in minutes
T_x = shift duration in minutes

The TWA concentration is used to determine the employee's exposure during the entire shift. OSHA recognizes the shift duration as an eight hour so the concentration must be adjusted for the eight hour shift.

All Cr(VI) TWA concentrations observed during the trials were below the OSHA PEL. The highest concentration measured was 3.75 µg/m^3. While the highest concentration measured was below the PEL it was above the action limit meaning control measures need to be implemented. General area samples collected did not detect a measurable concentration or revealed relatively low concentrations. Lack of detectable concentrations provides the conclusion that Cr(VI) did not migrate from the work area to the break facility via airborne mechanisms.

4.2.Manganese Air Sampling Results

A total of 16 Mn air samples were collected during the sampling. Sample weighted concentrations ranged from <0.000036 to 0.014 mg/m³ (Table 4, column 7). Concentrations reported as sample weighted concentration were converted to TWA concentrations utilizing the equation previously mentioned. Detectable concentrations of Mn were revealed in PBZ samples and 10 feet from the welder in all trials. Manganese was not detected in hallway or breakroom air samples. Trial three displayed the highest TWA concentration of all four trials, with a TWA of 0.014 mg/m³. Evaluation of the TWA reveals that employees were not exposed to limits at the OSHA PEL or the ACGIH TLV. This data suggests that measureable quantities of Mn was released into the work area within 10 feet of the welding operation, but did not migrate into the hallway or breakroom.

4.3.Wipe Sample Results

Wipe samples were collected to evaluate the potential migration of Cr(VI) and Mn outside of the welding area to the breakroom via the employees' hands or clothing. Potential migration can occur when employee does not utilize proper hygiene practices. Employees that perform welding at the facility wear welding jackets to protect their clothes and skin from the hazards associated with welding. Welding jackets are removed in the hallway prior to entering the breakroom and employees wash in a washroom adjacent to the hallway.

During each trial, four wipe samples were collected for a total of 16 wipe samples. At the location the employee took their break and meals two wipe samples were collected, one analyzed for Cr(VI) and the other analyzed for Mn. Two additional wipe samples were collected at a table adjacent from the employee performing the work; one sample was analyzed for Cr(VI) and the other sample was analyzed for Mn.

Results received from the lab were reported in mg/sample. In order to compare the lab results to the sampled area size, the results were converted to μg/cm². The following equation was utilized to achieve the μg/cm² concentration.

$$\mu g/cm^2 = \frac{\mu g/sample}{100\ cm^2}$$

Results from the wipe samples did not detect a measurable concentration of Cr(VI) at either of the tables sampled in any trial. However, Mn was detected in surface samples from all trials. Manganese surface concentrations ranged from 0.0034 to 0.014 μg/cm². Since 3-mil plastic was placed on the tables at the beginning of each shift and Mn was not detected in breakroom air samples, we postulate that the migration of low concentrations of Mn was due to employee transport. Migration of Mn was most likely attributed to the particles adhering to the employees' skin or clothing and then being transferred to the table during the break or meal.

5. Conclusion

The following conclusions were derived from this study:

1. Personal breathing zone sampling confirmed that employees were not exposed to levels of hexavalent chromium or Mn at or above the OELs. The research fails to reject the null hypotheses (NH_1) and (NH_7). The eight PBZ samples collected revealed concentrations were below the OEL for hexavalent chromium and Mn.

2. It was found that the concentrations at roughly ten feet away from the work area were below the analytical sampling method detection limit for hexavalent chromium except for one. The research rejects the null hypothesis (NH_2). Detectable concentrations of Mn were found in all four of the GA samples roughly ten feet away from the work area. Research rejects the null hypothesis (NH_8). Analytical testing conformed that migration occurred from the work area to an area roughly ten feet away from the work area.

3. Analyses of area air samples confirmed that the migration of hexavalent chromium and Mn did not occur in the hallway of the breakroom. All eight GA samples collected in the hallway of the breakroom were analyzed and detectable concentration of Cr(VI) and Mn were not detected. The research fails to reject the null hypotheses (NH_3) and (NH_9).

4. Research found that migration of hexavalent chromium and Mn did not occur through air in the breakroom where employees took shift breaks and meals. Detectable concentrations of Cr(VI) and Mn were not observed in the GA air samples in the breakroom. Research fails to reject the null hypotheses (NH_4) and (NH_{10}).

5. Wipe sample results did not reveal detectable concentrations of Cr(VI) on the table in the employee breakroom. Lack of detectable concentrations of Cr(VI) fails to reject the null hypothesis (H_5). Wipe samples analyzed for Mn revealed detectable concentrations of Mn on the table in the employee breakroom in all four wipe samples. It is postulated that migration of Mn occurred from the employees clothing. Research rejects the null hypothesis (NH_{11}).
6. Hexavalent chromium wipe samples collected at a desk adjacent to the table where employees took breaks did not reveal a detectable concentration of Cr(VI). The research fails to reject the null hypothesis (NH_6). Detectable concentrations of Mn were found, in all four trials, at the desk adjacent to the table where the employees took breaks. Research rejects the null hypothesis (NH_{12}).

The hypothesis conclusions determine that there is not a significant exposure to hexavalent chromium or Mn through the migration of those particles via air exposure to the breakroom. Migration of hexavalent chromium and Mn did occur from the work area to an area roughly ten feet from the work area. Concentrations of Cr(VI) and Mn from the work area to the area roughly ten feet away from the work area were all below the occupational exposure limits for both Cr(VI) and Mn.

Hexavalent chromium did not migrate to the desk the employee took breaks at through transfer of Cr(VI) from the employees clothing. All four wipe sample trials analyzed found a lack of detectable concentrations. Manganese did migrate from the work area to the desk where the employee took breaks via the employees clothing. All four wipe samples analyzed for Mn found detectable concentrations of Mn at the desk the employee took breaks. Wipe samples analyzed for Cr(VI) showed a lack of migration to the desk adjacent to the desk the employee takes break due to a lack of detectable concentrations of Cr(VI). Manganese wipe samples collected at the desk adjacent to desk the employee took breaks at showed detectable concentrations of Mn. Manganese migration at the desk adjacent to the desk the employee took breaks is believed to occur from employees not associated with the welding process. Material these employees work with has the potential to contain Mn from the coal that is burned at the facility. Additional research is required to determine the root cause of the migration of Mn experienced at the desk adjacent to the employee break table.

6. Recommendations and Limitations

Several recommendations can be concluded from this study. The first is to continue the sampling. To ensure employees are not being exposed to levels of hexavalent chromium or Mn in excess of the OELs, the site should conduct periodic sampling of the welders. An attempt should be made to target "worst case" scenarios where employees would be welding the majority of a shift. The more data that is collected, the more information the site will have on acceptable controls and possible changes to welding procedures.

Levels of hexavalent chromium were measured above the action limit set by OSHA. The site needs to ensure additional controls are implemented when employees are welding on stainless steel material. One control that should be utilized is local exhaust ventilation. If local exhaust ventilation is not feasible, employees must wear respiratory protection. At a minimum, employees should wear a half-masked air-purifying respirator with P100 filters.

Additional monitoring is required to quantify the amount of migration taking place in the work area. Inhalable and respirable fraction monitoring would allow the employer to compare results to size fractioned concentrations specified in the current ACGIH TLVs. Research showed that other heavy metals such as nickel and aluminum migrated into the breakroom. Additional monitoring may reveal that heavy metals other than the Cr(VI) or Mn are migrating at higher concentrations to the breakroom. Monitoring needs to be expanded to determine how migration of heavy metals is occurring at the table adjacent to the employee break table.

Another recommendation is that employees concentrate on proper hygiene practices. While concentrations of Mn did not exceed the OSHA PEL, there were detectable PBZ and area (10 feet away) concentrations during all four trials. In addition, Mn was detected on breakroom surfaces in the four trials. Employees do wear welding jackets that most likely keep a large amount of the welding particles away from the breakroom. Washing facilities are provided to employees and welding jackets should be washed on a frequent basis to limit the concentration of particle build up on them. Welding jackets should not be worn in the breakroom facility and should always be taken off prior to entering the breakroom.

There were a number of limitations during this study. One of the most notable limitations was the amount of welding during each trial. Employees working at the facility very rarely weld continuously for a full shift. Specific jobs may require only several minutes of welding and different jobs may require several hours of welding. Since the focus of this study was migration, it was determined that sampling for the majority of time the employee was welding was the best solution. Further evaluation with longer sample durations would provide more data on the migration of the Cr(VI) and Mn particles.

Another limitation is the size of the facility where the study was conducted. A better way to document the migration of the hexavalent chromium and Mn particles would have been to set up more general area samples throughout the facility. Samples collected provided good information on the transfer of particles into the breakroom, but there are several floors within the facility that could have been sampled as well. During large projects on the equipment at the facility, it might be beneficial to monitor each floor where a floor grating exists to ensure additional employees are not exposed to hexavalent chromium or Mn during the welding.

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Appendix A: OSHA ID-215

HEXAVALENT CHROMIUM IN WORKPLACE ATMOSPHERES

OSHA Method Number:	ID-215 (This method supersedes ID-103)
Matrix:	Air
OSHA Permissible Exposure Limit (proposed)	
Hexavalent Chromium [Cr(VI)]	
Time Weighted Average (TWA):	0.50 µg/m^3
Action Level (AL):	0.25 µg/m^3
Collection Device:	An air sample is collected using a 37-mm diameter polyvinyl chloride (PVC) filter (5-µm pore size) contained in a polystyrene cassette. A calibrated sampling pump is used to draw a representative air sample from the breathing zone of an employee through the cassette and collect particulate on the filter.
Recommended Sampling Rate:	2 liters per minute (L/min)
Recommended Air Volume:	
TWA and AL:	960 L (2 L/min for 480 min)
Analytical Procedure:	The hexavalent chromium, Cr(VI), is extracted from the PVC filter using an aqueous solution containing 10% sodium carbonate (Na_2CO_3)/ 2% sodium bicarbonate ($NaHCO_3$) and the mixture of phosphate buffer/magnesium sulfate [-10 mg as Mg (II)]. After dilution, an aliquot of this solution is analyzed for Cr(VI) by an ion chromatograph equipped with a UV-vis detector at 540-nm wavelength. A post-column derivatization of the Cr(VI) with 1,5-diphenyl carbazide is performed prior to detection.
Detection Limit	
Qualitative:	1.0×10^{-3} µg/m^3 as Cr(VI) (960-L air sample)
Quantitative:	3.0×10^{-3} µg/m^3 as Cr(VI) (960-L air sample)
Precision and Accuracy (Soluble and Insoluble)	
Validation Range:	0.12 to 0.42 µg/m^3 (960-L air sample)
CV_1(pooled):	0.059
Bias:	- 0.004
Overall Error:	±12.9%
Method Classification:	Validated Method
Chemists:	James C. Ku, Mary Eide
Date:	June, 1998

Commercial manufacturers and products mentioned in this method are for descriptive use only and do not constitute endorsements by USDOL-OSHA. Similar products from other sources can be substituted.

Branch of Inorganic Methods Development
OSHA Salt Lake Technical Center
Salt Lake City, Utah

Appendix B: NIOSH Method 7300

ELEMENTS by ICP (Nitric/Perchloric Acid Ashing) 7300

MW: Table 1 CAS: Table 2 RTECS: Table 2

METHOD: 7300, Issue 3 **EVALUATION:** PARTIAL **Issue 1:** 15 August 1990 **Issue 3:** 15 March 2003

OSHA: Table 2
NIOSH: Table 2
ACGIH: Table 2

PROPERTIES: Table 1

ELEMENTS:

aluminum*	calcium	lanthanum	nickel	strontium	tungsten*
antimony*	chromium*	lithium*	potassium	tellurium	vanadium*
arsenic	cobalt*	magnesium	phosphorus	tin	yittrium
barium	copper	manganese*	selenium	thallium	zinc
beryllium*	iron	molybdenum*	silver	titanium	zirconium*
cadmium	lead*				

*Some compounds of these elements require special sample treatment.

SAMPLING

SAMPLER: FILTER (0.8-µm, cellulose ester membrane, or 5.0-µm, polyvinyl chloride membrane)

FLOWRATE: 1 to 4 L/min

VOL-MIN: Table 1
-MAX: Table 1

SHIPMENT: routine

SAMPLE STABILITY: stable

BLANKS: 2 to 10 field blanks per set

ACCURACY

RANGE STUDIED: not determined

BIAS: not determined

OVERALL PRECISION ($\hat{S}_{rT}$): not determined

ACCURACY: not determined

MEASUREMENT

TECHNIQUE: INDUCTIVELY COUPLED ARGON PLASMA, ATOMIC EMISSION SPECTROSCOPY (ICP-AES)

ANALYTE: elements above

ASHING REAGENTS: conc. HNO_3 / conc. $HClO_4$ (4:1), 5 mL; 2mL increments added as needed

CONDITIONS: room temperature, 30 min; 150 °C to near dryness

FINAL SOLUTION: 4% HNO_3, 1% $HClO_4$, 25 mL

WAVELENGTH: depends upon element; Table 3

BACKGROUND CORRECTION: spectral wavelength shift

CALIBRATION: elements in 4% HNO_3, 1% $HClO_4$

RANGE: varies with element [1]

ESTIMATED LOD: Tables 3 and 4

PRECISION ($\hat{S}_r$): Tables 3 and 4

APPLICABILITY: The working range of this method is 0.005 to 2.0 mg/m^3 for each element in a 500-L air sample. This is simultaneous elemental analysis, not compound specific. Verify that the types of compounds in the samples are soluble with the ashing procedure selected.

INTERFERENCES: Spectral interferences are the primary interferences encountered in ICP-AES analysis. These are minimized by judicious wavelength selection, interelement correction factors and background correction [1-4].

OTHER METHODS: This issue updates issues 1 and 2 of Method 7300, which replaced P&CAM 351 [3] for trace elements. Flame atomic absorption spectroscopy (e.g., Methods 70XX) is an alternate analytical technique for many of these elements. Graphite furnace AAS (e.g., 7102 for Be, 7105 for Pb) is more sensitive.

NIOSH Manual of Analytical Methods (NMAM), Fourth Edition

Appendix C: Control Sample Analytical Report

ANALYTICAL REPORT

Report Date: May 17, 2013

Trevin Anderson
[redacted]

Phone: [redacted]

E-mail: [redacted]

Workorder: 34-1313030
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: [redacted] Media: PVC Filter Collected: 05/08/2013
Lab ID: 1313030001 Sampling Location: Scrubbers Received: 05/10/2013

Method: OSHA ID-215 **Sampling Parameter: Air Volume 748.8 L** **Analyzed: 05/16/2013**

Analyte	ug/sample	ug/m³	RL (ug/sample)
Hexavalent Chromium	<0.060	<0.080	0.060

Report Authorization

Method	Analyst	Peer Review
OSHA ID-215	Christopher Winter	Thomas T. McKay

Laboratory Contact Information

ALS Environmental
960 W Levoy Drive
Salt Lake City, Utah 84123

Phone: (801) 266-7700
Email: alslt.lab@ALSGlobal.com
Web: www.alsslc.com

Appendix D: Analytical Lab Reports

ALS

ANALYTICAL REPORT

Report Date: May 20, 2013

Trevin Anderson
[redacted]

[redacted]

Workorder: 34-1313403
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: PVC-001 | Media: PVC Filter | Collected: 05/10/2013
Lab ID: 1313403001 | Sampling Location: [redacted] | Received: 05/13/2013
Method: OSHA ID-215 | **Sampling Parameter: Air Volume 808 L** | **Analyzed: 05/16/2013**

Analyte	ug/sample	ug/m³	RL (ug/sample)
Hexavalent Chromium	<0.060	<0.074	0.060

Sample ID: PVC-002 | Media: PVC Filter | Collected: 05/10/2013
Lab ID: 1313403002 | Sampling Location: [redacted] | Received: 05/13/2013
Method: OSHA ID-215 | **Sampling Parameter: Air Volume 776 L** | **Analyzed: 05/16/2013**

Analyte	ug/sample	ug/m³	RL (ug/sample)
Hexavalent Chromium	<0.060	<0.077	0.060

Sample ID: PVC-003 | Media: PVC Filter | Collected: 05/10/2013
Lab ID: 1313403003 | Sampling Location: [redacted] | Received: 05/13/2013
Method: OSHA ID-215 | **Sampling Parameter: Air Volume 816 L** | **Analyzed: 05/16/2013**

Analyte	ug/sample	ug/m³	RL (ug/sample)
Hexavalent Chromium	<0.060	<0.074	0.060

Sample ID: PVC-004 | Media: PVC Filter | Collected: 05/10/2013
Lab ID: 1313403004 | Sampling Location: [redacted] | Received: 05/13/2013
Method: OSHA ID-215 | **Sampling Parameter: Air Volume 781 L** | **Analyzed: 05/16/2013**

Analyte	ug/sample	ug/m³	RL (ug/sample)
Hexavalent Chromium	<0.060	<0.077	0.060

ANALYTICAL REPORT

Workorder: 34-1313403
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: MCE-001 Media: MCE Filter Collected: 05/10/2013
Lab ID: 1313403005 Sampling Location: [redacted] Received: 05/13/2013

Method: NIOSH 7300 Mod. **Sampling Parameter:** Air Volume 784 L **Prepared:** 05/16/2013 **Analyzed:** 05/17/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Aluminum	**38**	**0.048**	1.5	5.0
Arsenic	<0.75	<0.00096	0.75	2.5
Beryllium	<0.0038	<0.0000048	0.0038	0.013
Cadmium	<0.023	<0.000029	0.023	0.075
Calcium	**73**	**0.093**	4.5	15
Chromium	**2.1**	**0.0027**	0.38	1.3
Cobalt	<0.023	<0.000029	0.023	0.075
Copper	**(0.49)**	**(0.00062)**	0.15	0.50
Iron	**62**	**0.079**	1.5	5.0
Lead	<0.38	<0.00048	0.38	1.3
Lithium	<0.15	<0.00019	0.15	0.50
Magnesium	**27**	**0.035**	0.38	1.3
Manganese	**1.2**	**0.0016**	0.038	0.13
Molybdenum	<0.46	<0.00059	0.46	1.5
Nickel	**1.7**	**0.0022**	0.038	0.13
Phosphorus	<1.5	<0.0019	1.5	5.0
Platinum	<1.1	<0.0014	1.1	3.8
Selenium	**(1.0)**	**(0.0013)**	0.75	2.5
Silver	<0.075	<0.000096	0.075	0.25
Sodium	**15**	**0.019**	1.1	3.8
Tellurium	<0.38	<0.00048	0.38	1.3
Thallium	<0.38	<0.00048	0.38	1.3
Titanium	**2.5**	**0.0032**	0.023	0.075
Vanadium	**(0.072)**	**(0.000092)**	0.023	0.075
Yttrium	<0.023	<0.000029	0.023	0.075
Zinc	**3.2**	**0.0041**	0.15	0.50
Zirconium	<0.15	<0.00019	0.15	0.50

Sample ID: MCE-002 Media: MCE Filter Collected: 05/10/2013
Lab ID: 1313403006 Sampling Location: [redacted] Received: 05/13/2013

Method: NIOSH 7300 Mod. **Sampling Parameter:** Air Volume 805 L **Prepared:** 05/16/2013 **Analyzed:** 05/17/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Aluminum	<1.5	<0.0019	1.5	5.0
Arsenic	**(0.96)**	**(0.0012)**	0.75	2.5
Beryllium	<0.0038	<0.0000047	0.0038	0.013
Cadmium	<0.023	<0.000028	0.023	0.075

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ANALYTICAL REPORT

Workorder: 34-1313403
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: MCE-002 | Media: MCE Filter | Collected: 05/10/2013
Lab ID: 1313403006 | Sampling Location: [redacted] | Received: 05/13/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter: Air Volume 805 L** | **Prepared:** 05/16/2013 **Analyzed:** 05/17/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Calcium	<4.5	<0.0056	4.5	15
Chromium	**(0.74)**	**(0.00092)**	0.38	1.3
Cobalt	<0.023	<0.000028	0.023	0.075
Copper	<0.15	<0.00019	0.15	0.50
Iron	<1.5	<0.0019	1.5	5.0
Lead	<0.38	<0.00047	0.38	1.3
Lithium	<0.15	<0.00019	0.15	0.50
Magnesium	**(0.75)**	**(0.00094)**	0.38	1.3
Manganese	<0.038	<0.000047	0.038	0.13
Molybdenum	<0.46	<0.00057	0.46	1.5
Nickel	**(0.043)**	**(0.000053)**	0.038	0.13
Phosphorus	<1.5	<0.0019	1.5	5.0
Platinum	<1.1	<0.0014	1.1	3.8
Selenium	<0.75	<0.00093	0.75	2.5
Silver	<0.075	<0.000093	0.075	0.25
Sodium	<1.1	<0.0014	1.1	3.8
Tellurium	<0.38	<0.00047	0.38	1.3
Thallium	<0.38	<0.00047	0.38	1.3
Titanium	**(0.055)**	**(0.000068)**	0.023	0.075
Vanadium	<0.023	<0.000028	0.023	0.075
Yttrium	<0.023	<0.000028	0.023	0.075
Zinc	<0.15	<0.00019	0.15	0.50
Zirconium	<0.15	<0.00019	0.15	0.50

Sample ID: MCE-003 | Media: MCE Filter | Collected: 05/10/2013
Lab ID: 1313403007 | Sampling Location: [redacted] | Received: 05/13/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter: Air Volume 832 L** | **Prepared:** 05/16/2013 **Analyzed:** 05/17/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Aluminum	**7.5**	**0.0091**	1.5	5.0
Arsenic	<0.75	<0.00090	0.75	2.5
Beryllium	<0.0038	<0.0000045	0.0038	0.013
Cadmium	<0.023	<0.000027	0.023	0.075
Calcium	**19**	**0.023**	4.5	15
Chromium	**(1.0)**	**(0.0012)**	0.38	1.3
Cobalt	<0.023	<0.000027	0.023	0.075
Copper	<0.15	<0.00018	0.15	0.50

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ANALYTICAL REPORT

Workorder: 34-1313403
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: MCE-003 | Media: MCE Filter | Collected: 05/10/2013
Lab ID: 1313403007 | Sampling Location: [redacted] | Received: 05/13/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter:** Air Volume 832 L | **Prepared:** 05/16/2013 **Analyzed:** 05/17/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Iron	**5.5**	**0.0066**	1.5	5.0
Lead	<0.38	<0.00045	0.38	1.3
Lithium	<0.15	<0.00018	0.15	0.50
Magnesium	**4.5**	**0.0055**	0.38	1.3
Manganese	**0.19**	**0.00022**	0.038	0.13
Molybdenum	<0.46	<0.00055	0.46	1.5
Nickel	**(0.11)**	**(0.00013)**	0.038	0.13
Phosphorus	<1.5	<0.0018	1.5	5.0
Platinum	<1.1	<0.0014	1.1	3.8
Selenium	<0.75	<0.00090	0.75	2.5
Silver	<0.075	<0.000090	0.075	0.25
Sodium	**(2.2)**	**(0.0026)**	1.1	3.8
Tellurium	<0.38	<0.00045	0.38	1.3
Thallium	**(0.39)**	**(0.00047)**	0.38	1.3
Titanium	**0.49**	**0.00059**	0.023	0.075
Vanadium	<0.023	<0.000027	0.023	0.075
Yttrium	<0.023	<0.000027	0.023	0.075
Zinc	**(0.19)**	**(0.00023)**	0.15	0.50
Zirconium	<0.15	<0.00018	0.15	0.50

Sample ID: MCE-004 | Media: MCE Filter | Collected: 05/10/2013
Lab ID: 1313403008 | Sampling Location: [redacted] | Received: 05/13/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter:** Air Volume 781 L | **Prepared:** 05/16/2013 **Analyzed:** 05/17/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Aluminum	<1.5	<0.0019	1.5	5.0
Arsenic	<0.75	<0.00096	0.75	2.5
Beryllium	<0.0038	<0.0000048	0.0038	0.013
Cadmium	<0.023	<0.000029	0.023	0.075
Calcium	<4.5	<0.0058	4.5	15
Chromium	**(0.52)**	**(0.00066)**	0.38	1.3
Cobalt	<0.023	<0.000029	0.023	0.075
Copper	<0.15	<0.00019	0.15	0.50
Iron	<1.5	<0.0019	1.5	5.0
Lead	<0.38	<0.00048	0.38	1.3
Lithium	<0.15	<0.00019	0.15	0.50
Magnesium	**(0.67)**	**(0.00085)**	0.38	1.3

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ANALYTICAL REPORT

Workorder: 34-1313403
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: MCE-004 | Media: MCE Filter | Collected: 05/10/2013
Lab ID: 1313403008 | Sampling Location: [redacted] | Received: 05/13/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter:** Air Volume 781 L | **Prepared:** 05/16/2013 **Analyzed:** 05/17/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Manganese	<0.038	<0.000048	0.038	0.13
Molybdenum	<0.46	<0.00059	0.46	1.5
Nickel	**(0.072)**	**(0.000093)**	0.038	0.13
Phosphorus	<1.5	<0.0019	1.5	5.0
Platinum	<1.1	<0.0014	1.1	3.8
Selenium	<0.75	<0.00096	0.75	2.5
Silver	<0.075	<0.000096	0.075	0.25
Sodium	<1.1	<0.0014	1.1	3.8
Tellurium	<0.38	<0.00048	0.38	1.3
Thallium	<0.38	<0.00048	0.38	1.3
Titanium	**(0.044)**	**(0.000056)**	0.023	0.075
Vanadium	<0.023	<0.000029	0.023	0.075
Yttrium	<0.023	<0.000029	0.023	0.075
Zinc	<0.15	<0.00019	0.15	0.50
Zirconium	<0.15	<0.00019	0.15	0.50

Sample ID: WIPE-001 | Media: PVC Filter | Collected: 05/10/2013
Lab ID: 1313403009 | Sampling Location: [redacted] | Received: 05/13/2013

Method: OSHA ID-215 | **Sampling Parameter:** Air Volume Not Provided | **Analyzed:** 05/16/2013

Analyte	ug/sample	ug/m³	RL (ug/sample)
Hexavalent Chromium	<0.060	NA	0.060

Sample ID: WIPE-002 | Media: PVC Filter | Collected: 05/10/2013
Lab ID: 1313403010 | Sampling Location: [redacted] | Received: 05/13/2013

Method: OSHA ID-215 | **Sampling Parameter:** Air Volume Not Provided | **Analyzed:** 05/16/2013

Analyte	ug/sample	ug/m³	RL (ug/sample)
Hexavalent Chromium	<0.060	NA	0.060

Sample ID: WIPE-003 | Media: Ghost Wipe | Collected: 05/10/2013
Lab ID: 1313403011 | Sampling Location: [redacted] | Received: 05/13/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter:** Area Not Provided | **Prepared:** 05/15/2013 **Analyzed:** 05/16/2013

Analyte	ug/sample	ug/100cm²	LOD (ug/sample)	RL (ug/sample)
Aluminum	**14**	NA	2.0	5.0

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ANALYTICAL REPORT

Workorder: 34-1313403
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: WIPE-003 Media: Ghost Wipe Collected: 05/10/2013
Lab ID: 1313403011 Sampling Location: [redacted] Received: 05/13/2013

Method: NIOSH 7300 Mod. **Sampling Parameter: Area Not Provided** **Prepared:** 05/15/2013 **Analyzed:** 05/16/2013

Analyte	ug/sample	ug/100cm²	LOD (ug/sample)	RL (ug/sample)
Arsenic	**(3.0)**	NA	1.9	6.3
Beryllium	<0.0021	NA	0.0021	0.0071
Cadmium	<0.023	NA	0.023	0.075
Calcium	**100**	NA	5.3	15
Chromium	**(0.15)**	NA	0.075	0.25
Cobalt	**(0.056)**	NA	0.023	0.075
Copper	**2.0**	NA	0.38	1.3
Iron	**22**	NA	3.0	10
Lead	<0.38	NA	0.38	1.3
Lithium	**0.92**	NA	0.22	0.50
Magnesium	**120**	NA	11	38
Manganese	**0.59**	NA	0.038	0.13
Molybdenum	**(1.2)**	NA	0.44	1.5
Nickel	**(0.22)**	NA	0.075	0.25
Phosphorus	**33**	NA	3.0	10
Platinum	<1.1	NA	1.1	3.8
Selenium	<8.3	NA	8.3	13
Silver	<0.075	NA	0.075	0.25
Sodium	**690**	NA	23	75
Tellurium	<1.1	NA	1.1	3.8
Thallium	**(1.8)**	NA	0.75	2.5
Titanium	**0.47**	NA	0.035	0.075
Vanadium	**0.088**	NA	0.040	0.075
Yttrium	<0.023	NA	0.023	0.075
Zinc	**76**	NA	4.3	13
Zirconium	<38	NA	38	130

Sample ID: WIPE-004 Media: Ghost Wipe Collected: 05/10/2013
Lab ID: 1313403012 Sampling Location: [redacted] Received: 05/13/2013

Method: NIOSH 7300 Mod. **Sampling Parameter: Area Not Provided** **Prepared:** 05/15/2013 **Analyzed:** 05/16/2013

Analyte	ug/sample	ug/100cm²	LOD (ug/sample)	RL (ug/sample)
Aluminum	**8.3**	NA	2.0	5.0
Arsenic	**(3.4)**	NA	1.9	6.3
Beryllium	<0.0021	NA	0.0021	0.0071
Cadmium	<0.023	NA	0.023	0.075
Calcium	**52**	NA	5.3	15

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ANALYTICAL REPORT

Workorder: 34-1313403
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: WIPE-004 | Media: Ghost Wipe | Collected: 05/10/2013
Lab ID: 1313403012 | Sampling Location: [redacted] | Received: 05/13/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter: Area Not Provided** | **Prepared:** 05/15/2013 **Analyzed:** 05/16/2013

Analyte	ug/sample	ug/100cm²	LOD (ug/sample)	RL (ug/sample)
Chromium	**(0.084)**	NA	0.075	0.25
Cobalt	**(0.032)**	NA	0.023	0.075
Copper	**1.9**	NA	0.38	1.3
Iron	**(4.8)**	NA	3.0	10
Lead	<0.38	NA	0.38	1.3
Lithium	**0.91**	NA	0.22	0.50
Magnesium	**100**	NA	11	38
Manganese	**0.40**	NA	0.038	0.13
Molybdenum	**(1.3)**	NA	0.44	1.5
Nickel	<0.075	NA	0.075	0.25
Phosphorus	**38**	NA	3.0	10
Platinum	<1.1	NA	1.1	3.8
Selenium	<8.3	NA	8.3	13
Silver	<0.075	NA	0.075	0.25
Sodium	**570**	NA	23	75
Tellurium	<1.1	NA	1.1	3.8
Thallium	**2.5**	NA	0.75	2.5
Titanium	**0.18**	NA	0.035	0.075
Vanadium	**(0.060)**	NA	0.040	0.075
Yttrium	<0.023	NA	0.023	0.075
Zinc	**82**	NA	4.3	13
Zirconium	<38	NA	38	130

Comments

Sample: 1313403005

The cassette for this sample was wiped with a clean ASTM type II water moistened MCE filter to transfer dust that had adhered to the inside of the cassette. This moistened MCE filter was digested along with the submitted MCE filter.

Sample: 1313403007

The cassette for this sample was wiped with a clean ASTM type II water moistened MCE filter to transfer dust that had adhered to the inside of the cassette. This moistened MCE filter was digested along with the submitted MCE filter.

Quality Control: NIOSH 7300 Mod. - (HBN: 107045)

The ghost wipe LMB 334052 was above the reporting limit for calcium (34.4 µg/sample), copper (1.69 µg/sample), lithium (0.784 µg/sample), magnesium (102 µg/sample), manganese (0.279 µg/sample), phosphorus (31.9 µg/sample), sodium (511 µg/sample), and zinc (70.3 µg/sample) so the LCS 334053 and LCSD 334054 results have been media blank corrected for calcium, copper, lithium, magnesium, manganese, phosphorus, sodium, and zinc with LMB 334052.

The sodium recovery for ghost wipe matrix LCS 334053 was low outside current Horizon limits after media blank correction. The sodium RPD between ghost wipe matrix LCS 334053 and LCSD 334054 was high outside current limits after media blank correction. Suspect variation in the sodium background of the ghost wipe media to be the cause of the low recovery and the high RPD.

ANALYTICAL REPORT

Workorder: 34-1315164
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: MCE-005 | Media: MCE Filter | Collected: 05/29/2013
Lab ID: 1315164005 | Sampling Location: [redacted] | Received: 05/31/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter: Air Volume 1015 L** | **Prepared:** 06/06/2013 **Analyzed:** 06/06/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Aluminum	**7.5**	**0.0074**	1.5	5.0
Arsenic	<0.75	<0.00074	0.75	2.5
Beryllium	**(0.0047)**	**(0.0000047)**	0.0038	0.013
Cadmium	<0.023	<0.000022	0.023	0.075
Calcium	**15**	**0.014**	4.5	15
Chromium	**4.4**	**0.0043**	0.38	1.3
Cobalt	**(0.027)**	**(0.000026)**	0.023	0.075
Copper	<0.15	<0.00015	0.15	0.50
Iron	**17**	**0.017**	1.5	5.0
Lead	<0.38	<0.00037	0.38	1.3
Lithium	<0.15	<0.00015	0.15	0.50
Magnesium	**3.1**	**0.0030**	0.38	1.3
Manganese	**0.39**	**0.00038**	0.038	0.13
Molybdenum	**1.5**	**0.0015**	0.46	1.5
Nickel	**3.4**	**0.0034**	0.038	0.13
Phosphorus	<1.5	<0.0015	1.5	5.0
Platinum	<1.1	<0.0011	1.1	3.8
Selenium	<0.75	<0.00074	0.75	2.5
Silver	<0.075	<0.000074	0.075	0.25
Sodium	**14**	**0.014**	1.1	3.8
Tellurium	<0.38	<0.00037	0.38	1.3
Thallium	<0.38	<0.00037	0.38	1.3
Titanium	**1.0**	**0.0010**	0.023	0.075
Vanadium	**(0.023)**	**(0.000022)**	0.023	0.075
Yttrium	<0.023	<0.000022	0.023	0.075
Zinc	**(0.33)**	**(0.00032)**	0.15	0.50
Zirconium	<0.15	<0.00015	0.15	0.50

Sample ID: MCE-006 | Media: MCE Filter | Collected: 05/29/2013
Lab ID: 1315164006 | Sampling Location: [redacted] | Received: 05/31/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter: Air Volume 1034.5 L** | **Prepared:** 06/06/2013 **Analyzed:** 06/06/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Aluminum	<1.5	<0.0015	1.5	5.0
Arsenic	<0.75	<0.00072	0.75	2.5
Beryllium	<0.0038	<0.0000036	0.0038	0.013
Cadmium	<0.023	<0.000022	0.023	0.075
Calcium	<4.5	<0.0043	4.5	15

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ANALYTICAL REPORT

Workorder: 34-1315164
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: MCE-006 | Media: MCE Filter | Collected: 05/29/2013
Lab ID: 1315164006 | Sampling Location: [redacted] | Received: 05/31/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter: Air Volume 1034.5 L** | **Prepared:** 06/06/2013 **Analyzed:** 06/06/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Chromium	<0.38	<0.00036	0.38	1.3
Cobalt	<0.023	<0.000022	0.023	0.075
Copper	<0.15	<0.00015	0.15	0.50
Iron	<1.5	<0.0015	1.5	5.0
Lead	<0.38	<0.00036	0.38	1.3
Lithium	<0.15	<0.00015	0.15	0.50
Magnesium	**(0.53)**	**(0.00051)**	0.38	1.3
Manganese	<0.038	<0.000036	0.038	0.13
Molybdenum	<0.46	<0.00044	0.46	1.5
Nickel	**(0.083)**	**(0.000080)**	0.038	0.13
Phosphorus	<1.5	<0.0015	1.5	5.0
Platinum	<1.1	<0.0011	1.1	3.8
Selenium	<0.75	<0.00072	0.75	2.5
Silver	<0.075	<0.000072	0.075	0.25
Sodium	<1.1	<0.0011	1.1	3.8
Tellurium	<0.38	<0.00036	0.38	1.3
Thallium	<0.38	<0.00036	0.38	1.3
Titanium	**(0.069)**	**(0.000066)**	0.023	0.075
Vanadium	<0.023	<0.000022	0.023	0.075
Yttrium	<0.023	<0.000022	0.023	0.075
Zinc	<0.15	<0.00015	0.15	0.50
Zirconium	<0.15	<0.00015	0.15	0.50

Sample ID: MCE-007 | Media: MCE Filter | Collected: 05/29/2013
Lab ID: 1315164007 | Sampling Location: [redacted] | Received: 05/31/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter: Air Volume 981.1 L** | **Prepared:** 06/06/2013 **Analyzed:** 06/06/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Aluminum	<1.5	<0.0015	1.5	5.0
Arsenic	<0.75	<0.00076	0.75	2.5
Beryllium	<0.0038	<0.0000038	0.0038	0.013
Cadmium	<0.023	<0.000023	0.023	0.075
Calcium	<4.5	<0.0046	4.5	15
Chromium	**(0.61)**	**(0.00062)**	0.38	1.3
Cobalt	<0.023	<0.000023	0.023	0.075
Copper	<0.15	<0.00015	0.15	0.50
Iron	<1.5	<0.0015	1.5	5.0
Lead	<0.38	<0.00038	0.38	1.3

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ANALYTICAL REPORT

Workorder: 34-1315164
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: MCE-007 Media: MCE Filter Collected: 05/29/2013
Lab ID: 1315164007 Sampling Location: [redacted] Received: 05/31/2013

Method: NIOSH 7300 Mod. **Sampling Parameter: Air Volume 981.1 L** **Prepared:** 06/06/2013 **Analyzed:** 06/06/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Lithium	<0.15	<0.00015	0.15	0.50
Magnesium	**(0.67)**	**(0.00069)**	0.38	1.3
Manganese	<0.038	<0.000038	0.038	0.13
Molybdenum	<0.46	<0.00047	0.46	1.5
Nickel	**(0.044)**	**(0.000045)**	0.038	0.13
Phosphorus	<1.5	<0.0015	1.5	5.0
Platinum	<1.1	<0.0011	1.1	3.8
Selenium	<0.75	<0.00076	0.75	2.5
Silver	<0.075	<0.000076	0.075	0.25
Sodium	<1.1	<0.0011	1.1	3.8
Tellurium	<0.38	<0.00038	0.38	1.3
Thallium	<0.38	<0.00038	0.38	1.3
Titanium	**(0.069)**	**(0.000070)**	0.023	0.075
Vanadium	<0.023	<0.000023	0.023	0.075
Yttrium	<0.023	<0.000023	0.023	0.075
Zinc	<0.15	<0.00015	0.15	0.50
Zirconium	<0.15	<0.00015	0.15	0.50

Sample ID: MCE-008 Media: MCE Filter Collected: 05/29/2013
Lab ID: 1315164008 Sampling Location: [redacted] Received: 05/31/2013

Method: NIOSH 7300 Mod. **Sampling Parameter: Air Volume 1060.9 L** **Prepared:** 06/06/2013 **Analyzed:** 06/06/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Aluminum	**(2.4)**	**(0.0023)**	1.5	5.0
Arsenic	**(1.4)**	**(0.0013)**	0.75	2.5
Beryllium	<0.0038	<0.0000035	0.0038	0.013
Cadmium	<0.023	<0.000021	0.023	0.075
Calcium	**(6.3)**	**(0.0059)**	4.5	15
Chromium	**(1.1)**	**(0.0010)**	0.38	1.3
Cobalt	**(0.053)**	**(0.000050)**	0.023	0.075
Copper	<0.15	<0.00014	0.15	0.50
Iron	**(3.4)**	**(0.0032)**	1.5	5.0
Lead	<0.38	<0.00035	0.38	1.3
Lithium	<0.15	<0.00014	0.15	0.50
Magnesium	**1.4**	**0.0013**	0.38	1.3
Manganese	**0.16**	**0.00015**	0.038	0.13
Molybdenum	**(0.46)**	**(0.00043)**	0.46	1.5
Nickel	**0.69**	**0.00065**	0.038	0.13

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ANALYTICAL REPORT

Workorder: 34-1315164
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: MCE-008 Media: MCE Filter Collected: 05/29/2013
Lab ID: 1315164008 Sampling Location: [redacted] Received: 05/31/2013

Method: NIOSH 7300 Mod. **Sampling Parameter:** Air Volume 1060.9 L **Prepared:** 06/06/2013 **Analyzed:** 06/06/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Phosphorus	<1.5	<0.0014	1.5	5.0
Platinum	<1.1	<0.0011	1.1	3.8
Selenium	<0.75	<0.00071	0.75	2.5
Silver	<0.075	<0.000071	0.075	0.25
Sodium	**(2.9)**	**(0.0028)**	1.1	3.8
Tellurium	<0.38	<0.00035	0.38	1.3
Thallium	<0.38	<0.00035	0.38	1.3
Titanium	**0.29**	**0.00028**	0.023	0.075
Vanadium	<0.023	<0.000021	0.023	0.075
Yttrium	<0.023	<0.000021	0.023	0.075
Zinc	**(0.32)**	**(0.00031)**	0.15	0.50
Zirconium	<0.15	<0.00014	0.15	0.50

Sample ID: WIPE-005 Media: Ghost Wipe Collected: 05/29/2013
Lab ID: 1315164009 Sampling Location: [redacted] Received: 05/31/2013

Method: NIOSH 7300 Mod. **Sampling Parameter:** Area Not Provided **Prepared:** 06/06/2013 **Analyzed:** 06/07/2013

Analyte	ug/sample	ug/100cm²	LOD (ug/sample)	RL (ug/sample)
Aluminum	**37**	NA	2.0	5.0
Arsenic	**(3.9)**	NA	1.9	6.3
Beryllium	**(0.0021)**	NA	0.0021	0.0071
Cadmium	<0.023	NA	0.023	0.075
Calcium	**140**	NA	5.3	15
Chromium	**2.0**	NA	0.075	0.25
Cobalt	**0.10**	NA	0.023	0.075
Copper	**2.6**	NA	0.38	1.3
Iron	**54**	NA	3.0	10
Lead	<0.38	NA	0.38	1.3
Lithium	**(0.55)**	NA	0.34	1.1
Magnesium	**130**	NA	11	38
Manganese	**1.4**	NA	0.038	0.13
Molybdenum	**2.1**	NA	0.51	1.7
Nickel	**3.3**	NA	0.075	0.25
Phosphorus	**47**	NA	3.0	10
Platinum	<1.1	NA	1.1	3.8
Selenium	<8.3	NA	8.3	13
Silver	<0.075	NA	0.075	0.25
Sodium	**760**	NA	23	75

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ANALYTICAL REPORT

Workorder: 34-1315164
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: WIPE-005 | Media: Ghost Wipe | Collected: 05/29/2013
Lab ID: 1315164009 | Sampling Location: [redacted] | Received: 05/31/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter: Area Not Provided** | **Prepared:** 06/06/2013 **Analyzed:** 06/07/2013

Analyte	ug/sample	ug/100cm²	LOD (ug/sample)	RL (ug/sample)
Tellurium	<1.1	NA	1.1	3.8
Thallium	**(1.9)**	NA	0.75	2.5
Titanium	**1.4**	NA	0.035	0.075
Vanadium	**0.16**	NA	0.040	0.075
Yttrium	<0.023	NA	0.023	0.075
Zinc	**95**	NA	4.3	13
Zirconium	<38	NA	38	130

Sample ID: WIPE-006 | Media: Ghost Wipe | Collected: 05/29/2013
Lab ID: 1315164010 | Sampling Location: [redacted] | Received: 05/31/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter: Area Not Provided** | **Prepared:** 06/06/2013 **Analyzed:** 06/07/2013

Analyte	ug/sample	ug/100cm²	LOD (ug/sample)	RL (ug/sample)
Aluminum	**6.8**	NA	2.0	5.0
Arsenic	**(3.5)**	NA	1.9	6.3
Beryllium	<0.0021	NA	0.0021	0.0071
Cadmium	<0.023	NA	0.023	0.075
Calcium	**81**	NA	5.3	15
Chromium	**(0.082)**	NA	0.075	0.25
Cobalt	**(0.044)**	NA	0.023	0.075
Copper	**2.4**	NA	0.38	1.3
Iron	**(4.7)**	NA	3.0	10
Lead	<0.38	NA	0.38	1.3
Lithium	**(0.54)**	NA	0.34	1.1
Magnesium	**110**	NA	11	38
Manganese	**0.39**	NA	0.038	0.13
Molybdenum	**(1.4)**	NA	0.51	1.7
Nickel	**0.64**	NA	0.075	0.25
Phosphorus	**43**	NA	3.0	10
Platinum	<1.1	NA	1.1	3.8
Selenium	<8.3	NA	8.3	13
Silver	<0.075	NA	0.075	0.25
Sodium	**700**	NA	23	75
Tellurium	<1.1	NA	1.1	3.8
Thallium	**(1.7)**	NA	0.75	2.5
Titanium	**0.29**	NA	0.035	0.075
Vanadium	**(0.069)**	NA	0.040	0.075
Yttrium	<0.023	NA	0.023	0.075

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ANALYTICAL REPORT

Workorder: 34-1315164
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: WIPE-006 | Media: Ghost Wipe | Collected: 05/29/2013
Lab ID: 1315164010 | Sampling Location: [redacted] | Received: 05/31/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter: Area Not Provided** | Prepared: 06/06/2013 | Analyzed: 06/07/2013

Analyte	ug/sample	ug/100cm²	LOD (ug/sample)	RL (ug/sample)
Zinc	**86**	NA	4.3	13
Zirconium	<38	NA	38	130

Sample ID: WIPE-007 | Media: Wipe | Collected: 05/29/2013
Lab ID: 1315164011 | Sampling Location [redacted] | Received: 05/31/2013

Method: OSHA ID-215 | **Sampling Parameter: Air Volume Not Provided** | Analyzed: 06/06/2013

Analyte	ug/sample	ug/m³	RL (ug/sample)
Hexavalent Chromium	<0.060	NA	0.060

Sample ID: WIPE-008 | Media: Wipe | Collected: 05/29/2013
Lab ID: 1315164012 | Sampling Location: [redacted] | Received: 05/31/2013

Method: OSHA ID-215 | **Sampling Parameter: Air Volume Not Provided** | Analyzed: 06/06/2013

Analyte	ug/sample	ug/m³	RL (ug/sample)
Hexavalent Chromium	<0.060	NA	0.060

Comments

Quality Control: NIOSH 7300 Mod. - (HBN: 108081)

The copper recoveries for MCE LCS 337018 (124%) and LCSD 337019 (128%) were outside current Horizon and method limits. The copper results for MCE field samples reported in this batch could potentially reflect a high bias based on the QC results

The arsenic recoveries for MCE LCS 337018 (110%) and LCSD 337019 (112%) were outside current Horizon limits but within method limits of +/- 20%. The results are reported without further comment.

The yttrium recoveries for MCE LCS 337018 (111%) and LCSD 337019 (113%) were outside current Horizon limits but within method limits of +/- 20%. The results are reported without further comment.

Quality Control: NIOSH 7300 Mod. - (HBN: 108097)

The ghost wipe LMB 337013 was above the reporting limit for calcium (36.4 µg/sample), magnesium (131 µg/sample), phosphorus (31.1 µg/sample), sodium (655 µg/sample), and zinc (25.0 µg/sample) so the LCS 336044 and LCSD 336045 results have been media blank corrected for calcium, magnesium, phosphorus, sodium, and zinc with LMB 336043.

The sodium RPD between LCS 337014 and LCSD 337015 was outside of current limits. The sodium recovery for both LCSD 337015 was below the reporting limit after media blank correction. Suspect varying ghost wipe media background to be the cause of the low recovery and therefore high RPD. The LCS 337014 was within limits so the data was reported as is without further comment. All other spiked analytes were within current limits.

Report Authorization

Method	Analyst	Peer Review
NIOSH 7300 Mod.	Peter P. Steen	Penny A. Foote
NIOSH 7300 Mod.	Penny A. Foote	Whitney Redd

ANALYTICAL REPORT

Report Date: June 08, 2013

Trevin Anderson
[redacted]

Phone: [redacted]

E-mail: [redacted]

Workorder: **34-1315425**
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: **PVC-009** Media: PVC Filter Collected: 05/30/2013
Lab ID: 1315425001 Sampling Location: [redacted] Received: 06/01/2013

Method: OSHA ID-215 **Sampling Parameter: Air Volume 1016.4 L** **Analyzed:** 06/07/2013

Analyte	ug/sample	ug/m³	RL (ug/sample)
Hexavalent Chromium	**2.8**	**2.8**	0.060

Sample ID: **PVC-010** Media: PVC Filter Collected: 05/30/2013
Lab ID: 1315425002 Sampling Location: [redacted] Received: 06/01/2013

Method: OSHA ID-215 **Sampling Parameter: Air Volume 1046.5 L** **Analyzed:** 06/07/2013

Analyte	ug/sample	ug/m³	RL (ug/sample)
Hexavalent Chromium	<0.060	<0.057	0.060

Sample ID: **PVC-011** Media: PVC Filter Collected: 05/30/2013
Lab ID: 1315425003 Sampling Location: [redacted] Received: 06/01/2013

Method: OSHA ID-215 **Sampling Parameter: Air Volume 957.4 L** **Analyzed:** 06/07/2013

Analyte	ug/sample	ug/m³	RL (ug/sample)
Hexavalent Chromium	<0.060	<0.063	0.060

Sample ID: **PVC-012** Media: PVC Filter Collected: 05/30/2013
Lab ID: 1315425004 Sampling Location: [redacted] Received: 06/01/2013

Method: OSHA ID-215 **Sampling Parameter: Air Volume 1042 L** **Analyzed:** 06/07/2013

Analyte	ug/sample	ug/m³	RL (ug/sample)
Hexavalent Chromium	<0.060	<0.058	0.060

ANALYTICAL REPORT

Workorder: 34-1315425
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: MCE-009 Media: MCE Filter Collected: 05/30/2013
Lab ID: 1315425005 Sampling Location: [redacted] Received: 06/01/2013

Method: NIOSH 7300 Mod. **Sampling Parameter: Air Volume 977 L** **Prepared:** 06/06/2013 **Analyzed:** 06/07/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Aluminum	**110**	**0.11**	1.5	5.0
Arsenic	**(1.5)**	**(0.0016)**	0.75	2.5
Beryllium	**0.024**	**0.000025**	0.0038	0.013
Cadmium	**(0.042)**	**(0.000043)**	0.023	0.075
Calcium	**210**	**0.22**	4.5	15
Chromium	**19**	**0.020**	0.38	1.3
Cobalt	**0.089**	**0.000091**	0.023	0.075
Copper	**2.6**	**0.0026**	0.15	0.50
Iron	**96**	**0.098**	1.5	5.0
Lead	<0.38	<0.00038	0.38	1.3
Lithium	**0.50**	**0.00051**	0.15	0.50
Magnesium	**69**	**0.070**	0.38	1.3
Manganese	**13**	**0.014**	0.038	0.13
Molybdenum	**8.4**	**0.0086**	0.51	1.7
Nickel	**8.4**	**0.0086**	0.038	0.13
Phosphorus	**(4.6)**	**(0.0047)**	1.5	5.0
Platinum	<1.1	<0.0012	1.1	3.8
Selenium	**(0.84)**	**(0.00086)**	0.75	2.5
Silver	**(0.22)**	**(0.00022)**	0.075	0.25
Sodium	**75**	**0.076**	1.1	3.8
Tellurium	<0.38	<0.00038	0.38	1.3
Thallium	**(0.46)**	**(0.00047)**	0.38	1.3
Titanium	**7.9**	**0.0081**	0.023	0.075
Vanadium	**0.50**	**0.00051**	0.023	0.075
Yttrium	**(0.064)**	**(0.000066)**	0.023	0.075
Zinc	**2.6**	**0.0026**	0.15	0.50
Zirconium	**0.75**	**0.00077**	0.15	0.50

Sample ID: MCE-010 Media: MCE Filter Collected: 05/30/2013
Lab ID: 1315425006 Sampling Location: [redacted] Received: 06/01/2013

Method: NIOSH 7300 Mod. **Sampling Parameter: Air Volume 1036.3 L** **Prepared:** 06/06/2013 **Analyzed:** 06/07/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Aluminum	<1.5	<0.0014	1.5	5.0
Arsenic	**(1.2)**	**(0.0011)**	0.75	2.5
Beryllium	**(0.0065)**	**(0.0000063)**	0.0038	0.013
Cadmium	<0.023	<0.000022	0.023	0.075
Calcium	<4.5	<0.0043	4.5	15

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ANALYTICAL REPORT

Workorder: 34-1315425
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: MCE-010 | Media: MCE Filter | Collected: 05/30/2013
Lab ID: 1315425006 | Sampling Location: [redacted] | Received: 06/01/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter: Air Volume 1036.3 L** | **Prepared:** 06/06/2013 **Analyzed:** 06/07/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Chromium	**(0.66)**	**(0.00064)**	0.38	1.3
Cobalt	<0.023	<0.000022	0.023	0.075
Copper	<0.15	<0.00014	0.15	0.50
Iron	<1.5	<0.0014	1.5	5.0
Lead	<0.38	<0.00036	0.38	1.3
Lithium	<0.15	<0.00014	0.15	0.50
Magnesium	**(0.93)**	**(0.00090)**	0.38	1.3
Manganese	<0.038	<0.000036	0.038	0.13
Molybdenum	<0.51	<0.00049	0.51	1.7
Nickel	**(0.12)**	**(0.00012)**	0.038	0.13
Phosphorus	<1.5	<0.0014	1.5	5.0
Platinum	<1.1	<0.0011	1.1	3.8
Selenium	<0.75	<0.00072	0.75	2.5
Silver	<0.075	<0.000072	0.075	0.25
Sodium	<1.1	<0.0011	1.1	3.8
Tellurium	<0.38	<0.00036	0.38	1.3
Thallium	<0.38	<0.00036	0.38	1.3
Titanium	**(0.069)**	**(0.000067)**	0.023	0.075
Vanadium	**(0.035)**	**(0.000034)**	0.023	0.075
Yttrium	<0.023	<0.000022	0.023	0.075
Zinc	<0.15	<0.00014	0.15	0.50
Zirconium	<0.15	<0.00014	0.15	0.50

Sample ID: MCE-011 | Media: MCE Filter | Collected: 05/30/2013
Lab ID: 1315425007 | Sampling Location: [redacted] | Received: 06/01/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter: Air Volume 1022 L** | **Prepared:** 06/06/2013 **Analyzed:** 06/07/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Aluminum	<1.5	<0.0015	1.5	5.0
Arsenic	**(0.83)**	**(0.00081)**	0.75	2.5
Beryllium	**(0.0040)**	**(0.0000039)**	0.0038	0.013
Cadmium	<0.023	<0.000022	0.023	0.075
Calcium	<4.5	<0.0044	4.5	15
Chromium	**(0.66)**	**(0.00065)**	0.38	1.3
Cobalt	<0.023	<0.000022	0.023	0.075
Copper	<0.15	<0.00015	0.15	0.50
Iron	<1.5	<0.0015	1.5	5.0
Lead	<0.38	<0.00037	0.38	1.3

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ANALYTICAL REPORT

Workorder: 34-1315425
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: MCE-011 Media: MCE Filter Collected: 05/30/2013
Lab ID: 1315425007 Sampling Location: [redacted] Received: 06/01/2013

Method: NIOSH 7300 Mod. **Sampling Parameter: Air Volume 1022 L** Prepared: 06/06/2013
Analyzed: 06/07/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Lithium	<0.15	<0.00015	0.15	0.50
Magnesium	**(0.65)**	**(0.00064)**	0.38	1.3
Manganese	<0.038	<0.000037	0.038	0.13
Molybdenum	<0.51	<0.00050	0.51	1.7
Nickel	**(0.092)**	**(0.000090)**	0.038	0.13
Phosphorus	<1.5	<0.0015	1.5	5.0
Platinum	<1.1	<0.0011	1.1	3.8
Selenium	<0.75	<0.00073	0.75	2.5
Silver	<0.075	<0.000073	0.075	0.25
Sodium	<1.1	<0.0011	1.1	3.8
Tellurium	<0.38	<0.00037	0.38	1.3
Thallium	**(0.42)**	**(0.00041)**	0.38	1.3
Titanium	**(0.034)**	**(0.000033)**	0.023	0.075
Vanadium	<0.023	<0.000022	0.023	0.075
Yttrium	<0.023	<0.000022	0.023	0.075
Zinc	<0.15	<0.00015	0.15	0.50
Zirconium	<0.15	<0.00015	0.15	0.50

Sample ID: MCE-012 Media: MCE Filter Collected: 05/30/2013
Lab ID: 1315425008 Sampling Location: [redacted] Received: 06/01/2013

Method: NIOSH 7300 Mod. **Sampling Parameter: Air Volume 957.5 L** Prepared: 06/06/2013
Analyzed: 06/07/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Aluminum	**(3.3)**	**(0.0034)**	1.5	5.0
Arsenic	<0.75	<0.00078	0.75	2.5
Beryllium	<0.0038	<0.0000039	0.0038	0.013
Cadmium	<0.023	<0.000023	0.023	0.075
Calcium	**28**	**0.029**	4.5	15
Chromium	**(0.76)**	**(0.00079)**	0.38	1.3
Cobalt	<0.023	<0.000023	0.023	0.075
Copper	<0.15	<0.00016	0.15	0.50
Iron	**(4.3)**	**(0.0045)**	1.5	5.0
Lead	<0.38	<0.00039	0.38	1.3
Lithium	<0.15	<0.00016	0.15	0.50
Magnesium	**8.5**	**0.0088**	0.38	1.3
Manganese	**(0.086)**	**(0.000090)**	0.038	0.13
Molybdenum	<0.51	<0.00053	0.51	1.7
Nickel	**0.25**	**0.00026**	0.038	0.13

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ANALYTICAL REPORT

Workorder: 34-1315425
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: MCE-012 | Media: MCE Filter | Collected: 05/30/2013
Lab ID: 1315425008 | Sampling Location: [redacted] | Received: 06/01/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter: Air Volume 957.5 L** | **Prepared:** 06/06/2013 | **Analyzed:** 06/07/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Phosphorus	<1.5	<0.0016	1.5	5.0
Platinum	<1.1	<0.0012	1.1	3.8
Selenium	<0.75	<0.00078	0.75	2.5
Silver	<0.075	<0.000078	0.075	0.25
Sodium	**18**	**0.019**	1.1	3.8
Tellurium	<0.38	<0.00039	0.38	1.3
Thallium	**(0.39)**	**(0.00040)**	0.38	1.3
Titanium	**0.24**	**0.00025**	0.023	0.075
Vanadium	**(0.028)**	**(0.000029)**	0.023	0.075
Yttrium	<0.023	<0.000023	0.023	0.075
Zinc	**(0.24)**	**(0.00025)**	0.15	0.50
Zirconium	<0.15	<0.00016	0.15	0.50

Sample ID: WIPE-009 | Media: Ghost Wipe | Collected: 05/30/2013
Lab ID: 1315425009 | Sampling Location: [redacted] | Received: 06/01/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter: Area Not Provided** | **Prepared:** 06/06/2013 | **Analyzed:** 06/07/2013

Analyte	ug/sample	ug/100cm²	LOD (ug/sample)	RL (ug/sample)
Aluminum	**(4.2)**	NA	2.0	5.0
Arsenic	**(2.4)**	NA	1.9	6.3
Beryllium	<0.0021	NA	0.0021	0.0071
Cadmium	<0.023	NA	0.023	0.075
Calcium	**50**	NA	5.3	15
Chromium	<0.075	NA	0.075	0.25
Cobalt	**(0.051)**	NA	0.023	0.075
Copper	**1.8**	NA	0.38	1.3
Iron	**(4.1)**	NA	3.0	10
Lead	<0.38	NA	0.38	1.3
Lithium	**(0.46)**	NA	0.34	1.1
Magnesium	**100**	NA	11	38
Manganese	**0.34**	NA	0.038	0.13
Molybdenum	**(1.6)**	NA	0.51	1.7
Nickel	**0.32**	NA	0.075	0.25
Phosphorus	**41**	NA	3.0	10
Platinum	<1.1	NA	1.1	3.8
Selenium	<8.3	NA	8.3	13
Silver	<0.075	NA	0.075	0.25
Sodium	**500**	NA	23	75

Results Continued on Next Page

ANALYTICAL REPORT

Workorder: **34-1315425**
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: **WIPE-009** Media: Ghost Wipe Collected: 05/30/2013
Lab ID: 1315425009 Sampling Location: [redacted] Received: 06/01/2013

Method: NIOSH 7300 Mod. **Sampling Parameter: Area Not Provided** **Prepared:** 06/06/2013 **Analyzed:** 06/07/2013

Analyte	ug/sample	ug/100cm²	LOD (ug/sample)	RL (ug/sample)
Tellurium	<1.1	NA	1.1	3.8
Thallium	**(2.0)**	NA	0.75	2.5
Titanium	**0.20**	NA	0.035	0.075
Vanadium	**(0.053)**	NA	0.040	0.075
Yttrium	<0.023	NA	0.023	0.075
Zinc	**78**	NA	4.3	13
Zirconium	<38	NA	38	130

Sample ID: **WIPE-010** Media: Ghost Wipe Collected: 05/30/2013
Lab ID: 1315425010 Sampling Location: [redacted] Received: 06/01/2013

Method: NIOSH 7300 Mod. **Sampling Parameter: Area Not Provided** **Prepared:** 06/06/2013 **Analyzed:** 06/07/2013

Analyte	ug/sample	ug/100cm²	LOD (ug/sample)	RL (ug/sample)
Aluminum	**5.5**	NA	2.0	5.0
Arsenic	<1.9	NA	1.9	6.3
Beryllium	<0.0021	NA	0.0021	0.0071
Cadmium	<0.023	NA	0.023	0.075
Calcium	**52**	NA	5.3	15
Chromium	<0.075	NA	0.075	0.25
Cobalt	**(0.047)**	NA	0.023	0.075
Copper	**2.2**	NA	0.38	1.3
Iron	**(4.5)**	NA	3.0	10
Lead	<0.38	NA	0.38	1.3
Lithium	**(0.53)**	NA	0.34	1.1
Magnesium	**110**	NA	11	38
Manganese	**0.47**	NA	0.038	0.13
Molybdenum	**(1.6)**	NA	0.51	1.7
Nickel	**(0.22)**	NA	0.075	0.25
Phosphorus	**50**	NA	3.0	10
Platinum	<1.1	NA	1.1	3.8
Selenium	**(8.7)**	NA	8.3	13
Silver	<0.075	NA	0.075	0.25
Sodium	**530**	NA	23	75
Tellurium	<1.1	NA	1.1	3.8
Thallium	**(2.1)**	NA	0.75	2.5
Titanium	**0.24**	NA	0.035	0.075
Vanadium	**(0.059)**	NA	0.040	0.075
Yttrium	<0.023	NA	0.023	0.075

Results Continued on Next Page

ANALYTICAL REPORT

Workorder: **34-1315425**
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: **WIPE-010** Media: Ghost Wipe Collected: 05/30/2013
Lab ID: 1315425010 Sampling Location: [redacted] Received: 06/01/2013

Method: NIOSH 7300 Mod. **Sampling Parameter: Area Not Provided** **Prepared:** 06/06/2013 **Analyzed:** 06/07/2013

Analyte	ug/sample	ug/100cm²	LOD (ug/sample)	RL (ug/sample)
Zinc	**97**	NA	4.3	13
Zirconium	<38	NA	38	130

Sample ID: **WIPE-011** Media: Wipe Collected: 05/30/2013
Lab ID: 1315425011 Sampling Location: [redacted] Received: 06/01/2013

Method: OSHA ID-215 **Sampling Parameter: Area Not Provided** **Analyzed:** 06/07/2013

Analyte	ug/sample	RL (ug/sample)
Hexavalent Chromium	<0.060	0.060

Sample ID: **WIPE-012** Media: Wipe Collected: 05/30/2013
Lab ID: 1315425012 Sampling Location: [redacted] Received: 06/01/2013

Method: OSHA ID-215 **Sampling Parameter: Area Not Provided** **Analyzed:** 06/07/2013

Analyte	ug/sample	RL (ug/sample)
Hexavalent Chromium	<0.060	0.060

Comments

Quality Control: NIOSH 7300 Mod. - (HBN: 108096)

The LRB 337098 was above the reporting limit for iron equivalent to 32.1 µg/sample and zinc 7.75 µg/sample but the LMB 337099 and field blank sample 1315463003 were both well below the reporting limit for iron and zinc. Therefore, it is noted here but no reagent blank corrections were performed.

The MCE LMB 337099 was above the reporting limit for magnesium equivalent to 2.60 µg/sample so the LCS 337100 and LCSD 337101 results have been media blank corrected for magnesium with LMB 337099.

The arsenic recoveries for LCS 337100 (108.48%) and LCSD 337101 (109.96%) were outside current Horizon limits but within method limits of +/- 20%. The results are reported without further comment.

The copper recoveries for LCSD 337101 (120.9%) were outside current Horizon and method limits. The copper results for field samples reported in this batch could potentially reflect a high bias based on the QC results.

Quality Control: NIOSH 7300 Mod. - (HBN: 108097)

The ghost wipe LMB 337013 was above the reporting limit for calcium (36.4 µg/sample), magnesium (131 µg/sample), phosphorus (31.1 µg/sample), sodium (655 µg/sample), and zinc (25.0 µg/sample) so the LCS 336044 and LCSD 336045 results have been media blank corrected for calcium, magnesium, phosphorus, sodium, and zinc with LMB 336043.

The sodium RPD between LCS 337014 and LCSD 337015 was outside of current limits. The sodium recovery for both LCSD 337015 was below the reporting limit after media blank correction. Suspect varying ghost wipe media background to be the cause of the low recovery and therefore high RPD. The LCS 337014 was within limits so the data was reported as is without further comment. All other spiked analytes were within current limits.

ANALYTICAL REPORT

Report Date: June 08, 2013

Trevin Anderson
[redacted]

Phone: [redacted]

E-mail: [redacted]

Workorder: **34-1315426**
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: **PVC-013** Media: PVC Filter Collected: 05/31/2013
Lab ID: 1315426001 Sampling Location: [redacted] Received: 06/01/2013

Method: OSHA ID-215 **Sampling Parameter: Air Volume 483.8 L** **Analyzed:** 06/07/2013

Analyte	ug/sample	ug/m³	RL (ug/sample)
Hexavalent Chromium	<0.060	<0.12	0.060

Sample ID: **PVC-014** Media: PVC Filter Collected: 05/31/2013
Lab ID: 1315426002 Sampling Location: [redacted] Received: 06/01/2013

Method: OSHA ID-215 **Sampling Parameter: Air Volume 492.6 L** **Analyzed:** 06/07/2013

Analyte	ug/sample	ug/m³	RL (ug/sample)
Hexavalent Chromium	<0.060	<0.12	0.060

Sample ID: **PVC-015** Media: PVC Filter Collected: 05/31/2013
Lab ID: 1315426003 Sampling Location: [redacted] Received: 06/01/2013

Method: OSHA ID-215 **Sampling Parameter: Air Volume 480.8 L** **Analyzed:** 06/07/2013

Analyte	ug/sample	ug/m³	RL (ug/sample)
Hexavalent Chromium	<0.060	<0.12	0.060

Sample ID: **PVC-016** Media: PVC Filter Collected: 05/31/2013
Lab ID: 1315426004 Sampling Location: [redacted] Received: 06/01/2013

Method: OSHA ID-215 **Sampling Parameter: Air Volume 395.2 L** **Analyzed:** 06/07/2013

Analyte	ug/sample	ug/m³	RL (ug/sample)
Hexavalent Chromium	<0.060	<0.15	0.060

ANALYTICAL REPORT

Workorder: 34-1315426
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: MCE-013 | Media: MCE Filter | Collected: 05/31/2013
Lab ID: 1315426005 | Sampling Location: [redacted] | Received: 06/01/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter: Air Volume 483.8 L** | **Prepared:** 06/06/2013 **Analyzed:** 06/07/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Aluminum	**24**	**0.049**	1.5	5.0
Arsenic	**(1.1)**	**(0.0023)**	0.75	2.5
Beryllium	<0.0038	<0.0000078	0.0038	0.013
Cadmium	<0.023	<0.000047	0.023	0.075
Calcium	**57**	**0.12**	4.5	15
Chromium	**1.5**	**0.0030**	0.38	1.3
Cobalt	<0.023	<0.000047	0.023	0.075
Copper	**(0.17)**	**(0.00034)**	0.15	0.50
Iron	**15**	**0.031**	1.5	5.0
Lead	<0.38	<0.00078	0.38	1.3
Lithium	**(0.15)**	**(0.00031)**	0.15	0.50
Magnesium	**17**	**0.035**	0.38	1.3
Manganese	**0.78**	**0.0016**	0.038	0.13
Molybdenum	<0.51	<0.0011	0.51	1.7
Nickel	**0.70**	**0.0014**	0.038	0.13
Phosphorus	**(1.6)**	**(0.0034)**	1.5	5.0
Platinum	<1.1	<0.0023	1.1	3.8
Selenium	<0.75	<0.0016	0.75	2.5
Silver	<0.075	<0.00016	0.075	0.25
Sodium	**9.4**	**0.019**	1.1	3.8
Tellurium	<0.38	<0.00078	0.38	1.3
Thallium	**(0.84)**	**(0.0017)**	0.38	1.3
Titanium	**1.6**	**0.0033**	0.023	0.075
Vanadium	**(0.070)**	**(0.00014)**	0.023	0.075
Yttrium	<0.023	<0.000047	0.023	0.075
Zinc	**2.3**	**0.0047**	0.15	0.50
Zirconium	<0.15	<0.00031	0.15	0.50

Sample ID: MCE-014 | Media: MCE Filter | Collected: 05/31/2013
Lab ID: 1315426006 | Sampling Location: [redacted] | Received: 06/01/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter: Air Volume 490.3 L** | **Prepared:** 06/06/2013 **Analyzed:** 06/07/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Aluminum	<1.5	<0.0031	1.5	5.0
Arsenic	<0.75	<0.0015	0.75	2.5
Beryllium	<0.0038	<0.0000076	0.0038	0.013
Cadmium	<0.023	<0.000046	0.023	0.075
Calcium	<4.5	<0.0092	4.5	15

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ANALYTICAL REPORT

Workorder: **34-1315426**
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: **MCE-014** Media: MCE Filter Collected: 05/31/2013
Lab ID: 1315426006 Sampling Location: [redacted] Received: 06/01/2013

Method: NIOSH 7300 Mod. **Sampling Parameter: Air Volume 490.3 L** **Prepared:** 06/06/2013 **Analyzed:** 06/07/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Chromium	**(0.49)**	**(0.00099)**	0.38	1.3
Cobalt	<0.023	<0.000046	0.023	0.075
Copper	<0.15	<0.00031	0.15	0.50
Iron	<1.5	<0.0031	1.5	5.0
Lead	<0.38	<0.00076	0.38	1.3
Lithium	<0.15	<0.00031	0.15	0.50
Magnesium	**(0.64)**	**(0.0013)**	0.38	1.3
Manganese	<0.038	<0.000076	0.038	0.13
Molybdenum	<0.51	<0.0010	0.51	1.7
Nickel	**(0.088)**	**(0.00018)**	0.038	0.13
Phosphorus	<1.5	<0.0031	1.5	5.0
Platinum	<1.1	<0.0023	1.1	3.8
Selenium	<0.75	<0.0015	0.75	2.5
Silver	<0.075	<0.00015	0.075	0.25
Sodium	<1.1	<0.0023	1.1	3.8
Tellurium	<0.38	<0.00076	0.38	1.3
Thallium	<0.38	<0.00076	0.38	1.3
Titanium	**(0.043)**	**(0.000088)**	0.023	0.075
Vanadium	<0.023	<0.000046	0.023	0.075
Yttrium	<0.023	<0.000046	0.023	0.075
Zinc	<0.15	<0.00031	0.15	0.50
Zirconium	<0.15	<0.00031	0.15	0.50

Sample ID: **MCE-015** Media: MCE Filter Collected: 05/31/2013
Lab ID: 1315426007 Sampling Location: [redacted] Received: 06/01/2013

Method: NIOSH 7300 Mod. **Sampling Parameter: Air Volume 495 L** **Prepared:** 06/06/2013 **Analyzed:** 06/07/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Aluminum	<1.5	<0.0030	1.5	5.0
Arsenic	<0.75	<0.0015	0.75	2.5
Beryllium	<0.0038	<0.0000076	0.0038	0.013
Cadmium	<0.023	<0.000045	0.023	0.075
Calcium	<4.5	<0.0091	4.5	15
Chromium	**(0.55)**	**(0.0011)**	0.38	1.3
Cobalt	<0.023	<0.000045	0.023	0.075
Copper	<0.15	<0.00030	0.15	0.50
Iron	<1.5	<0.0030	1.5	5.0
Lead	<0.38	<0.00076	0.38	1.3

Results Continued on Next Page

ANALYTICAL REPORT

Workorder: **34-1315426**
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: **MCE-015** | Media: MCE Filter | Collected: 05/31/2013
Lab ID: 1315426007 | Sampling Location: [redacted] | Received: 06/01/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter: Air Volume 495 L** | **Prepared:** 06/06/2013 **Analyzed:** 06/07/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Lithium	<0.15	<0.00030	0.15	0.50
Magnesium	**(0.47)**	**(0.00095)**	0.38	1.3
Manganese	<0.038	<0.000076	0.038	0.13
Molybdenum	<0.51	<0.0010	0.51	1.7
Nickel	**(0.061)**	**(0.00012)**	0.038	0.13
Phosphorus	<1.5	<0.0030	1.5	5.0
Platinum	<1.1	<0.0023	1.1	3.8
Selenium	<0.75	<0.0015	0.75	2.5
Silver	<0.075	<0.00015	0.075	0.25
Sodium	<1.1	<0.0023	1.1	3.8
Tellurium	<0.38	<0.00076	0.38	1.3
Thallium	<0.38	<0.00076	0.38	1.3
Titanium	**(0.031)**	**(0.000063)**	0.023	0.075
Vanadium	<0.023	<0.000045	0.023	0.075
Yttrium	<0.023	<0.000045	0.023	0.075
Zinc	<0.15	<0.00030	0.15	0.50
Zirconium	<0.15	<0.00030	0.15	0.50

Sample ID: **MCE-016** | Media: MCE Filter | Collected: 05/31/2013
Lab ID: 1315426008 | Sampling Location: [redacted] | Received: 06/01/2013

Method: NIOSH 7300 Mod. | **Sampling Parameter: Air Volume 395.2 L** | **Prepared:** 06/06/2013 **Analyzed:** 06/07/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Aluminum	**(2.8)**	**(0.0072)**	1.5	5.0
Arsenic	<0.75	<0.0019	0.75	2.5
Beryllium	<0.0038	<0.0000095	0.0038	0.013
Cadmium	<0.023	<0.000057	0.023	0.075
Calcium	**(8.2)**	**(0.021)**	4.5	15
Chromium	**(0.84)**	**(0.0021)**	0.38	1.3
Cobalt	<0.023	<0.000057	0.023	0.075
Copper	<0.15	<0.00038	0.15	0.50
Iron	**(1.7)**	**(0.0043)**	1.5	5.0
Lead	<0.38	<0.00095	0.38	1.3
Lithium	<0.15	<0.00038	0.15	0.50
Magnesium	**2.2**	**0.0056**	0.38	1.3
Manganese	**(0.097)**	**(0.00024)**	0.038	0.13
Molybdenum	<0.51	<0.0013	0.51	1.7
Nickel	**(0.089)**	**(0.00022)**	0.038	0.13

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ANALYTICAL REPORT

Workorder: 34-1315426
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: MCE-016 Media: MCE Filter Collected: 05/31/2013
Lab ID: 1315426008 Sampling Location: [redacted] Received: 06/01/2013

Method: NIOSH 7300 Mod. **Sampling Parameter: Air Volume 395.2 L** **Prepared:** 06/06/2013 **Analyzed:** 06/07/2013

Analyte	ug/sample	mg/m³	LOD (ug/sample)	RL (ug/sample)
Phosphorus	<1.5	<0.0038	1.5	5.0
Platinum	<1.1	<0.0028	1.1	3.8
Selenium	<0.75	<0.0019	0.75	2.5
Silver	<0.075	<0.00019	0.075	0.25
Sodium	**(1.7)**	**(0.0043)**	1.1	3.8
Tellurium	<0.38	<0.00095	0.38	1.3
Thallium	**(0.53)**	**(0.0013)**	0.38	1.3
Titanium	**0.21**	**0.00053**	0.023	0.075
Vanadium	<0.023	<0.000057	0.023	0.075
Yttrium	<0.023	<0.000057	0.023	0.075
Zinc	**(0.21)**	**(0.00054)**	0.15	0.50
Zirconium	<0.15	<0.00038	0.15	0.50

Sample ID: WIPE-013 Media: Ghost Wipe Collected: 05/31/2013
Lab ID: 1315426009 Sampling Location: [redacted] Received: 06/01/2013

Method: NIOSH 7300 Mod. **Sampling Parameter: Area Not Provided** **Prepared:** 06/06/2013 **Analyzed:** 06/07/2013

Analyte	ug/sample	ug/100cm²	LOD (ug/sample)	RL (ug/sample)
Aluminum	**24**	NA	2.0	5.0
Arsenic	**(2.4)**	NA	1.9	6.3
Beryllium	<0.0021	NA	0.0021	0.0071
Cadmium	<0.023	NA	0.023	0.075
Calcium	**110**	NA	5.3	15
Chromium	**(0.24)**	NA	0.075	0.25
Cobalt	**0.092**	NA	0.023	0.075
Copper	**2.7**	NA	0.38	1.3
Iron	**11**	NA	3.0	10
Lead	<0.38	NA	0.38	1.3
Lithium	**(0.58)**	NA	0.34	1.1
Magnesium	**130**	NA	11	38
Manganese	**0.92**	NA	0.038	0.13
Molybdenum	**1.7**	NA	0.51	1.7
Nickel	**1.3**	NA	0.075	0.25
Phosphorus	**50**	NA	3.0	10
Platinum	<1.1	NA	1.1	3.8
Selenium	<8.3	NA	8.3	13
Silver	<0.075	NA	0.075	0.25
Sodium	**870**	NA	23	75

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ANALYTICAL REPORT

Workorder: **34-1315426**
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: **WIPE-013** Media: Ghost Wipe Collected: 05/31/2013
Lab ID: 1315426009 Sampling Location: [redacted] Received: 06/01/2013

Method: NIOSH 7300 Mod. **Sampling Parameter: Area Not Provided** **Prepared:** 06/06/2013 **Analyzed:** 06/07/2013

Analyte	ug/sample	ug/100cm²	LOD (ug/sample)	RL (ug/sample)
Tellurium	<1.1	NA	1.1	3.8
Thallium	**(1.9)**	NA	0.75	2.5
Titanium	**0.81**	NA	0.035	0.075
Vanadium	**0.099**	NA	0.040	0.075
Yttrium	<0.023	NA	0.023	0.075
Zinc	**100**	NA	4.3	13
Zirconium	<38	NA	38	130

Sample ID: **WIPE-014** Media: Ghost Wipe Collected: 05/31/2013
Lab ID: 1315426010 Sampling Location: [redacted] Received: 06/01/2013

Method: NIOSH 7300 Mod. **Sampling Parameter: Area Not Provided** **Prepared:** 06/06/2013 **Analyzed:** 06/07/2013

Analyte	ug/sample	ug/100cm²	LOD (ug/sample)	RL (ug/sample)
Aluminum	**9.8**	NA	2.0	5.0
Arsenic	**(1.9)**	NA	1.9	6.3
Beryllium	<0.0021	NA	0.0021	0.0071
Cadmium	<0.023	NA	0.023	0.075
Calcium	**79**	NA	5.3	15
Chromium	**(0.11)**	NA	0.075	0.25
Cobalt	**(0.057)**	NA	0.023	0.075
Copper	**2.4**	NA	0.38	1.3
Iron	**(5.3)**	NA	3.0	10
Lead	<0.38	NA	0.38	1.3
Lithium	**(0.50)**	NA	0.34	1.1
Magnesium	**110**	NA	11	38
Manganese	**0.48**	NA	0.038	0.13
Molybdenum	**(1.6)**	NA	0.51	1.7
Nickel	**0.30**	NA	0.075	0.25
Phosphorus	**51**	NA	3.0	10
Platinum	<1.1	NA	1.1	3.8
Selenium	<8.3	NA	8.3	13
Silver	<0.075	NA	0.075	0.25
Sodium	**860**	NA	23	75
Tellurium	<1.1	NA	1.1	3.8
Thallium	**(1.9)**	NA	0.75	2.5
Titanium	**0.43**	NA	0.035	0.075
Vanadium	**0.079**	NA	0.040	0.075
Yttrium	<0.023	NA	0.023	0.075

Results Continued on Next Page

ANALYTICAL REPORT

Workorder: **34-1315426**
Client Project ID: [redacted]
Purchase Order: [redacted]
Project Manager: Rand Potter

Analytical Results

Sample ID: **WIPE-014** Media: Ghost Wipe Collected: 05/31/2013
Lab ID: 1315426010 Sampling Location: [redacted] Received: 06/01/2013

Method: NIOSH 7300 Mod. **Sampling Parameter: Area Not Provided** Prepared: 06/06/2013 Analyzed: 06/07/2013

Analyte	ug/sample	ug/100cm²	LOD (ug/sample)	RL (ug/sample)
Zinc	**93**	NA	4.3	13
Zirconium	<38	NA	38	130

Sample ID: **WIPE-015** Media: Wipe Collected: 05/31/2013
Lab ID: 1315426011 Sampling Location [redacted] Received: 06/01/2013

Method: OSHA ID-215 **Sampling Parameter: Area Not Provided** Analyzed: 06/07/2013

Analyte	ug/sample	RL (ug/sample)
Hexavalent Chromium	<0.060	0.060

Sample ID: **WIPE-016** Media: Wipe Collected: 05/31/2013
Lab ID: 1315426012 Sampling Location: [redacted] Received: 06/01/2013

Method: OSHA ID-215 **Sampling Parameter: Area Not Provided** Analyzed: 06/07/2013

Analyte	ug/sample	RL (ug/sample)
Hexavalent Chromium	<0.060	0.060

Comments

Quality Control: NIOSH 7300 Mod. - (HBN: 108096)

The LRB 337098 was above the reporting limit for iron equivalent to 32.1 µg/sample and zinc 7.75 µg/sample but the LMB 337099 and field blank sample 1315463003 were both well below the reporting limit for iron and zinc. Therefore, it is noted here but no reagent blank corrections were performed.

The MCE LMB 337099 was above the reporting limit for magnesium equivalent to 2.60 µg/sample so the LCS 337100 and LCSD 337101 results have been media blank corrected for magnesium with LMB 337099.

The arsenic recoveries for LCS 337100 (108.48%) and LCSD 337101 (109.96%) were outside current Horizon limits but within method limits of +/- 20%. The results are reported without further comment.

The copper recoveries for LCSD 337101 (120.9%) were outside current Horizon and method limits. The copper results for field samples reported in this batch could potentially reflect a high bias based on the QC results.

Quality Control: NIOSH 7300 Mod. - (HBN: 108097)

The ghost wipe LMB 337013 was above the reporting limit for calcium (36.4 µg/sample), magnesium (131 µg/sample), phosphorus (31.1 µg/sample), sodium (655 µg/sample), and zinc (25.0 µg/sample) so the LCS 336044 and LCSD 336045 results have been media blank corrected for calcium, magnesium, phosphorus, sodium, and zinc with LMB 336043.

The sodium RPD between LCS 337014 and LCSD 337015 was outside of current limits. The sodium recovery for both LCSD 337015 was below the reporting limit after media blank correction. Suspect varying ghost wipe media background to be the cause of the low recovery and therefore high RPD. The LCS 337014 was within limits so the data was reported as is without further comment. All other spiked analytes were within current limits.

SIGNATURE SHEET

This thesis has been examined and approved for acceptance by the Department of Industrial Hygiene, Montana Tech of The University of Montana, Butte, Montana, on the sixth day of December, 2010.

Julie Hart, CIH, Associate Professor
Department of Industrial Hygiene
Chair, Examination Committee

Dr. Terry Spear, Professor and Department Head
Department of Industrial Hygiene
Member, Examination Committee

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