# Analysis of levels of metal dust produced by galvanized grinding activities

by

Paul T. Schulz

A Research Paper
Submitted in Partial Fulfillment of the
Requirements for the
Master of Science Degree
in

Risk Control

Approved: Three (3) Semester Credits
[redacted]
Elbert Sorrell, Ed.D.

The Graduate School

University of Wisconsin-Stout

September 2011

**The Graduate School**
**University of Wisconsin-Stout**

**Menomonie, WI**

**Author:** **Schulz, Paul T.**

**Title:** *Analysis of levels of organic dust produced by galvanized metal hot-work activities*

**Graduate Degree/ Major:** MS Risk Control

**Research Adviser:** Elbert Sorrell, Ed.D.

**Month/Year:** September 2011

**Number of Pages:** 53

**Style Manual Used:** American Psychological Association, 6th edition

## Abstract

The purpose of the study was to identify the current levels of metal exposure that are experienced by employees who are performing metal grinding activities. According to literature, galvanized metal contains levels of lead, antimony, aluminum, zinc, cadmium, copper, chromium, manganese, and nickel. OSHA as well as ACGIH has created exposure limits to help protect employees from the adverse health affects caused by the inhalation or contact with said metals. Air samples were collected while the researcher performed grinding activities on galvanized metal. The results indicated that the metals identified as components of the galvanized coating do have the potential to become airborne during grinding activities. Three of the nine samples presented lead results that were above the OSHA PEL and the ACGIH allowable level, while the average of the nine results exceeded the OSHA action level of

0.03mg/m3. The conclusion of the research is that employees may be experiencing an overexposure during grinding activities on galvanized metal. The overall recommendation of the study is to provide better working situations for the employees through improved ventilation and/or through work practice alterations.

# Table of Contents

# List of Tables

# Chapter I: Introduction

"In 2008, welders, cutters, solderers, and brazers held approximately 412,300 jobs in the United States. About 65 percent of welding jobs were found in manufacturing (United States Department, 2009)." Galvanizing is the process of coating steel or iron with a layer of zinc. This layer helps to prevent against the effects of corrosion. The zinc baths used in the coating process contain trace amounts of other metals. These metals include lead, aluminum, chromium, and manganese. When hot work is performed on galvanized metal it creates hazards for the workers which include dust, gases and fumes. Fumes are created through the process of welding pieces of metal. Zinc oxide fume is the most common hazard associated with welding on galvanized metal and exposure to zinc oxide fumes can lead to metal fume fever. "Metal fume fever is a "flu-like illness that develops after inhalation of metal fumes with symptoms beginning 3-10 hours after exposure (El-Zein, & Infante-Rivard, 2005)." According to the literature review tremendous amounts of research has been conducted in reference to the hazards presented by welding on galvanized metal but there is a gap in the information surrounding the potential hazards surrounding grinding on galvanized metal. Grinding activities must occur on the metal to ensure a proper weld is achieved. According to the American Galvanizers Association the coating should be removed from the welding area on both sides of the work pieces, allowing two to four inches on either side of the welding zone (Livelli, & Langill, Ph.D., 1998). Grinding dust is created as a byproduct and could contain toxicants which are harmful to the human body. Many contaminates of the zinc coating are regulated by the Occupational Safety and Health Administration (OSHA) and the American Conference of Industrial Hygienists (ACGIH) due to the potential adverse health effects.

Table 1.1

OSHA Permissible Exposure Limits

| Trace Metal | Respirable Dust | Total Dust | ACGIH TLV |
|---|---|---|---|
| **Lead** | --- | 0.05 mg/m$^3$ | 0.05 mg/m$^3$ |
| **Aluminum** | 5 mg/m$^3$ | 15 mg/m$^3$ | 1 mg/m$^3$ (R)* |
| **Chromium** | --- | 0.005 mg/m$^3$ | 0.5 mg/m$^3$ |
| **Manganese** | --- | 5 mg/m$^3$ (Ceiling) | 0.2 mg/m$^3$ |

* Respirable Fraction

## Statement of the Problem

A lack of industrial hygiene monitoring data regarding metal grinding practices has potentially placed the grinder and other proximity employees at risk of over exposure to metal dust.

## Purpose of the Study

The purpose of the study is to identify the current levels of metal exposure that are experienced by employees who are performing metal grinding activities. For the purpose of this study, the researcher will serve as the employee for which samples will be taken. Data will be collected through the use of mixed cellulose ester between 2010 and 2011 in Company XYZ.

## Research Questions

There are three research questions this study will attempt to answer. They include:

1. Does galvanized metal contain other heavy metals besides zinc?
2. What are the metals that are airborne while hot-work is being performed on the galvanized metal and at what levels are they present?
3. What are the health hazards to the employees who are performing hot-work on galvanized metal caused by the heavy metal components?

## Background and Significance

This study is the result of an employee of company XYZ who posed the question "what other hazards may be created or are present during hot-work on galvanized metal?" Little was known within the company as well as outside of the company. After a review of the material safety data sheets (MSDS), it was concluded that there is a possibility of additional hazards besides the known hazard of zinc. Other metals have more stringent regulatory limits and are highly toxic. Company XYZ determined that a study needed to be conducted to identify the levels of exposure that their employees were currently experiencing. This study will help to insure that Company XYZ is complaint with the regulations while keeping the employees safe. If compliance does not occur Company XYZ could be at risk for obtaining fines as well as tarnishing their reputation. Financial consequences include the cost for insurance and workers compensation. Not only does this study help to minimize the potential for accumulating fines and increasing costs but it helps the company to be proactive in protecting their employees from hazards. If employees are not presented with the hazards then the company does not have to worry about how they will pay for a loss if it does occur. Using the information gathered from the study Company XYZ may be able to save money from future loss caused by either a loss of money due to fines and medical costs or due to a loss of production caused be a willingness of employees to participate due to the adverse symptoms they are feeling.

This study could impact the way Company XYZ conducts grinding activities on galvanized metal. Company XYZ has standards in place for performing hot work within the shops but has no guidelines for performing the work in a modular (poly shelter) in the facility. The results of this study will help to defend the proposal for procedures when it comes to performing hot work in the field. Based on study conclusion, Company XYZ may extrapolate the findings through their United States plants.

## Limitations of the Study

The study is being conducted with several limitations.

1. Detection limits and lab testing methods are limited to the capabilities set forth by either the lab or manufacturer.
2. Sufficient sampling material is limited to materials that have been scraped or are left over from a completed job.
3. Wind or other environmental conditions could change the sampling results.
4. Sample size for the study may be too small to make proper recommendations.

## Assumptions of the Study

Assumptions of the study include the following:

1. All particulates collected on the sampling media were created from the grinding activities performed by the subject.
2. All samples sent to the lab for analysis will be accurately evaluated per the chosen sampling method.
3. The base metal has even distribution of the contaminants.
4. The study is being conducted under a worst case scenario.

5. All grinding wheels and types of grinders will produce similar dust volumes.
6. Materials that contain similar pre-work levels will contain similar airborne concentrations.

## Definition of Terms

The following section will provide explanations of the key terms that are used throughout the research.

**ACGIH Threshold Limit Value**. The Threshold Limit Values are developed as guidelines to assist in the control of health hazards. These limits are for a conventional 8- hour workday and a 40-hour workweek. (TLVs and BEIs. (2011).

**Ceiling**. "The concentration that should not be exceeded during any part of the working exposure (TLVs and BEIs. (2011)."

**Hot-work.** Work involving electric or gas welding, cutting, brazing, or similar flame or spark-producing operations (United States Department, 2000).

**OSHA Permissible Exposure Limit**. "An exposure limit published and enforced by OSHA as a legal standard. Most PELs are expressed as eight hour average airborne concentrations of substances to which it is believed most workers may be exposed for a working lifetime without developing serious illness (Plog, & Quinlan, 2002)."

# Chapter II: Literature Review

## Galvanized Metal

A literature review has been conducted to gather industry information regarding the history and process of galvanization, trace metals contained in galvanized products, health effects of the identified trace metals, hot-work hazards, and a case study review of similar studies.

"Used to provide corrosion protection since the early 19$^{th}$ century, zinc remains one of the premier coatings to defend steel from the elements (Lindsley, 2008)." Galvanized steel continues to be one of the most used types of corrosion and protection agents in the industry. Zinc coatings are applied to a range of steel products including sheet metal, wire, tube, steel sections, and fabricated goods (Porter, 1993). This coating is applied using several different methods: hot-dip galvanizing, zinc spraying, zinc plating, sherardizing, and zinc dust painting. All of the methods consist of a zinc base with other elements including lead, chromium, and aluminum. These elements are either found naturally in the steel or are additive in the coating mixture.

The first record of zinc being used in construction dates back to 79 AD. In 1742 a French chemist named P.J Malouin presented a method of coating iron with molten zinc to the French Royal Academy. Luigi Galvani, galvanizing's namesake, discovered the electrochemical process in 1772 while conducting an experiment with frog legs. Following Luigi's finding, in 1801, Alessandro Volta continued the research and he discovered that the electro potential between two metals creates a corrosion cell. Michael Faraday furthered the previous studies and in 1829 identified zinc's sacrificial action while performing an experiment with zinc, salt water, and nails. The first patent for the early galvanizing process was given to a French engineer

Stanislaus Tranquille Modeste Sorel in 1837. After one hundred and fifty years galvanizing is found in nearly every industry and application including utilities, pulp and paper, automotive, maritime, and numerous others that use iron or steel (American Galvanizers Association, 2008). The U.S Federal Highway Administration released a two-year study in 2002 that looked at the direct cost of corrosion in nearly every industry. The study concluded that $276 billion dollars could be directly linked to corrosion in the U.S. or the per capita cost of corrosion is nearly $970 per person per year (The National Association of Corrosion Engineers, 2002).

Galvanized coatings are applied using several different methods; hot-dip galvanizing, zinc spray, electro galvanizing, mechanical plating, and zinc painting. "Hot-dip galvanizing is known generally as galvanizing (Zinc coatings,2006)." "This process is a simple batch process where steel, suspended by chain or wire from a crane, is moved through the plant and dipped in a series of tanks. The first three tanks are used to clean and prepare the steel for galvanizing. Once the steel is cleaned it is immersed in the galvanizing kettle (Lindsley,2008)." "The material is completely immersed in a bath consisting of a minimum of 98% pure molten zinc. The bath chemistry is specified by the American Society for Testing and Materials in Specification B 6. The bath temperature is maintained at about 449 degrees Celsius (Hot-dip galvanizing for corrosion, 2000)." Due to the immersion, the zinc is able to penetrate into the recesses and other areas that may be difficult to access using other coating methods. An advantage of hot-dip galvanizing is the ability to perform the coating under any weather conditions. This is because the process is performed at the factory while most brush and spray applied coating depend upon proper weather and humidity conditions for correct application (Hot-dip galvanizing for corrosion, 2000). Hot-dip galvanizing can be used for materials ranging in size from small nuts and bolts to very large structural shapes. In addition to single batch galvanizing there is a method called continuous sheet galvanizing. This process requires the material to be fed through the baths continuous. Normal applications of this method include sheet metal and steel wire.

The baths that are utilized for the coating process do not consist of pure zinc. Trace metals are added to the zinc to increase the fluidity of the bathing liquid, create the appearance of spangle, and enhance the adhesiveness of the zinc. A result of additives in the coating bath is the appearance of spangle on the surface of galvanized steel. "Spangle is used to define the surface appearance of galvanized steel sheets, it includes the typical snowflake-like or six fold star pattern that is visible to the unaided eye. In most galvanized coatings on steel sheets; the most common reason for the well-defined dendritic growth pattern is the presence of lead in the coating (Steel Mills of the World, 2003)." Lead is a common impurity in zinc. Lead is the most common metal found in zinc-containing ores, and this refining process carried it through as an impurity in the zinc (Steel Mills of the World, 2003). Along with lead; tin, cadmium, antimony, and copper may be alloys used to create the appearance of spangle (Dr.Galv, 2002). Not only does lead aid in the development of spangle but it help to increase the fluidity of the bathing liquid. "After it was legislated that lead was to be removed from our environment wherever possible the mills began removing lead and substituting antimony to produce a spangle (Semtrogard, 2002)." Antimony ores are mined and are either changed into antinomy metal or combined with oxygen to form antimony oxide. Small amounts of antimony are usually mixed with other metals such as lead and zinc to form mixtures of metals called alloys (Agency for Toxic, 1992). Antimony is added to zinc baths to help with the creation of spangle. "Antimony influences spangle formation in a similar fashion to lead. The final result is a smooth, visible spangled coating. Typically, the amount of antimony in the coating bath is about 0.03 to 0.10% (International Zinc Association,2011)." Along with antimony, lead, copper, cadmium and tin galvanized metal baths often have aluminum added to increase the adhesion of the coating to the base metal. "A small amount of aluminum is added to the zinc as an inhibitor, greatly restricting the rate at which the zinc-iron alloying reaction proceeds in the early stages of immersion. In a bath without aluminum, there is high diffusion rate between molten zinc and any immersed steel (International Zinc Association, 2009)." There are many other metals that could be present in either the base metal or as a contaminant within the zinc coating. Many MSDSs show the base metal and alloys which may include calcium, carbon, copper, manganese, phosphorus, silicon, sulfur, iron, nickel, chromium. These metals may become airborne if the grinding activities. According to OSHA 29CFR 1910.1200 (g)(2)(i)(C)(1) "the chemical and common name(s) of all ingredients which have been determined to be health hazards, and which comprise 1% or greater of the composition, except that chemical identified as carcinogens under paragraph (d) of this section shall be listed if the concentration are 0.1% or greater on the MSDS." This regulation explains why on many MSDSs you will not find all metals that could be present. OSHA has developed permissible exposure limits (PELs) for the hazards listed above along with approximately 500 others with the goal of protecting the worker from overexposures.

PELs are limits placed on substances in the air, either the total amount or concentration that an employee can experience. An eight hour time weighted average is used as the bases for OSHA PELs (United States Department of Labor, 2006). Even though amounts or concentration of substances may not exceed the PEL, OSHA has developed substance specific action levels. These levels tend to be half of the PEL value for that specific substance. Exposures that reach or exceed the action level cause additional action to be performed by the employer. These actions could include worker training, additional PPE and medical surveillance (Nims, 1999). In addition to OSHA PELs the American Conference of Governmental Industrial Hygienist

(ACGIH) publishes a reference guide with recommendation for exposure limits. The data is derived from peer reviewed literature within the disciplines of industrial hygiene, toxicology, occupational medicine, and epidemiology. Exposure levels are set at a level which will allow the employee to perform work without adverse health effects (TLVs and BEIs, 2011).

Table 2.1

Exposure Limits and Health Effects

| **Trace Metal** | Respirable Dust | Total Dust | Action Level | ACGIH | Health Effects |
|---|---|---|---|---|---|
| **Lead** | --- | 0.05 mg/m$^3$ | 0.03 mg/m$^3$ | 0.05 mg/m$^3$ | Increased blood pressure, digestive problems, kidney damage, nerve disorders, sleep problems, muscle and joint pain |
| **Aluminum** | 5 mg/m$^3$ | 15 mg/m$^3$ | -- | 1 mg/m$^3$ (r) | Nervous system and respiratory issues, |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | impaired lung function and fibrosis |
| **Chromium** | --- | 0.005 mg/m$^3$ | -- | 0.5 mg/m$^3$ | irritation eyes and skin, lung fibrosis |
| **Manganese** | --- | 5 mg/m$^3$ (Ceiling) | -- | 0.2 mg/m$^3$ | Forgetfulness and nerve damage, Parkinson, lung embolism and bronchitis, weakness |
| **Antimony** | -- | 0.5 mg/m$^3$ | -- | 0.5 mg/m$^3$ | Irritation to eyes, skin, nose, throat, mouth, headache, nausea, cramps, |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | anorexia |
| **Copper** | -- | 1 mg/m$^3$ | -- | 1mg/m$^3$ | Irritation to eyes, nose, pharynx, metallic taste, liver and kidney damage |
| **Nickel** | -- | 1 mg/m3 | -- | -- | Allergic asthma, cough, shortness of breath, decreased smell, lung damage |
| **Zinc** | -- | 15 mg/m$^3$ | -- | 2 mg/m$^3$ (r) | Metal fume fever, chills, muscle ache, dry throat, cough, weakness, blurred vision, low back pain, chest tightness, |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | decreased pulmonary function |
| **Cadmium** | -- | 0.005 mg/m$^3$ | 0.0025 mg/m$^3$ | 0.01 mg/m$^3$ | Cough, chest tightness, substernal pain, headache, chills, muscle aches, difficulty breathing, could potentially be a occupational Carcinogen |

## Hot Work

“Hot Work” is defined as any temporary operation involving open flames or producing heat and/or sparks. This includes, but is not limited to: brazing, cutting, grinding, soldering, torch-applied roofing, and welding (Hot work safety procedure, 2010).” “These activities are hazardous because they pose a unique combination of both safety and health risk to more than 500,000 workers in a wide variety of industries (United States Department of Labor, 2007).”

These hazards arise from both the physical contact to the flames or sparks and also the byproducts of the activity. The byproducts consist of fumes, gases and, dust which may be harmful to the employee's health.

"Welding is defined as joining pieces of metal by the use of heat, pressure, or both. There are many different types of welding and associated process. Some of the most common types of welding include: arc welding, which includes "stick", or shielding metal arc welding (SMAW), the shielding methods of metal inert gas (MIG) and tungsten inert gas (TIG), plasma arc welding (PAW), and submerged arc welding (SAW) (Health hazards of Welding, 2009)." Welding galvanized metal is very similar to welding bare steel in that you use the same welding practices and procedures. "The difference between welding galvanized steel and welding uncoated steel is a result of the low vaporization temperature of the zinc coating. Zinc melts at about 900 degrees Fahrenheit and vaporizes at about 1650 degrees Fahrenheit. This can cause an increase in the volume of welding fumes along with the removal of the protective zinc coating (Welding galvanized steel, 2003)." Lead, zinc oxide, and cadmium can all be created as a result of welding on galvanized, plated, or painted metals (United States Department of Labor, 2011). Fumes are defined as "solid particles which originate from welding consumables, the base metal and any coating present on the base metal (Fumes and Gases, 2005)." Along with toxic fumes harmful gases can be produced during hot activities including "carbon monoxide, hydrogen fluoride, nitrogen oxide, and ozone (Labor Occupational Safety, 2003).

"For galvanized structural fabrications, the zinc coating should be removed at least one to four inches from either side of the intended weld zone and on both sides of the piece. Grinding back the zinc coating is the preferred and most common method (American Galvanizers Association, 2008)." These grinding activities produce dust that must be controlled. "Dusts are tiny solid particles scattered or suspended in the air (Organic dust, 2011)." "Dust particles are classified in two categories; total dust and respirable dust. Total dust refers to all dust particles that can be effectively collected using a filter cassette. Respirable dust refers to those dust particles small enough in size to get through the protective mechanisms of the nose upper airway and reach the gas exchange region of the lung (SKC Gulf Coast Inc., 2011)." The human body has built in defenses to help protect the lungs from being affected by small dust particles. "When a person breathes in, particles suspended in the air enter the nose, but not all of them reach the lungs. The nose is an efficient filter. Most large particles are stopped in it, until removed mechanically by blowing the nose or sneezing (Canadian Centre for, 2002)."

"Metal fume fever occurs in humans who inhale high concentration of zinc oxide (Barceloux, 1999)." The symptoms of metal fume fever tend to last up to 48 hours, while rare, severe cases have been reported. (Bydash, Kasmani, & Naraharisetty, 2010). "Metal fume fever was first described in 1822 as "brass founder's ague" among brass founders, metal fume fever has been labeled Monday fever, foundry fever, copper fever, smelter chills, brass chills and welders ague (Merchant, & Webby, 2001)." In a case study conducted by John Merchant and Rosalind Webby they explored a case involving a 26 year male that entered the emergency department via ambulance, four hours after oxycutting zinc-coated steel. This study looked at symptoms and current accepted management of metal fume fever. Fever, chills, dyspnea, non-productive cough, pleuritic chest pain, dry throat, intense thirst, profuse sweating, and nausea and vomiting are all common symptoms of metal fume fever. The most common treatment of metal fume fever is simply oxygen and rest (Merchant, & Webby, 2001). Overexposure to zinc oxide is one of the most common problems with regards to welding on galvanized steel which can be backed by the large amount of research that has been conducted around this topic.

## Previous Case Studies

A study conducted in July 1994 at Johnson Controls, Inc in Lexington, Kentucky by the National Institute for Occupational Safety and Health (NIOSH) evaluated workers exposure to contaminants generated during production welding of galvanized steel. The study looked at three damper production lines at the facility, each one having a welding station that required one full time worker. The welding process was metal inert-gas (MIG), using carbon dioxide as the inert gas shield. Local exhaust was installed at each line. Air sampling was conducted using established NIOSH analytical methods. Calibrated air sampling pumps were attached to select workers and connected, via tubing. The pump flow rates were approximately two liters per minute (L/m). The sample collection media was placed in the employees' breathing zone under the worker's welding helmet. The samples were collected on five micrometer poly-vinyl chloride filters. The samples were drawn throughout the employee's work-shift. A total of five samples were collected each for approximately three hours. Post-calibration was completed and the samples were then sent to Data Chem for analysis. Element specific analysis was conducted according to NIOSH method 7300. Blanks were submitted with the samples. Samples were collected for carbon monoxide, nitrogen dioxide, and ozone. In this study they also collected surface samples to determine the level of metal dust that accumulated at the work stations and employee break room. Wash & Dri pre-moistened toilettes were used to wipe 100 square centimeters of surface area. OSHA Industrial Hygiene Technical Manual, and NIOSH method 0700, lead in surface wipe samples was used as a guide for sampling protocol. The samples along with the blanks were sent to the laboratory for analysis. The ventilation in the area was also monitored to determine if it was adequate for the workers exposure. The air velocity was measured using an anemometer that measures in feet-per-minute. In conclusion the study found that all sample results showed that exposure to the contaminants sampled were below the applicable NIOSH REL for the sampling period. The highest level of zinc oxide detected was 1.71 mg/m$^3$ and this was the highest of all the contaminants (iron, manganese) detected. The surface sampling came back with zinc levels between 36-78 micrograms per 100 square centimeter surface area. Zinc and copper were the predominant elements detected with trace levels of lead, cadmium, and cobalt was found. The ventilation hoods were not effective at removing welding fumes from the worker's breathing zone. It was concluded that there was no inhalation hazard for the employees sampled although it was discussed that food and beverage consumption should be restricted to non-manufacturing areas. Most of the recommendation consisted of making changes to the ventilation system as well as the respirator program. (Kiefer, 1994)

In December, 1993 NIOSH conducted an industrial hygiene study at UNR- Rohn Manufacturing in Peoria, Illinois. Employees were complaining of headaches and nausea which was believed to be caused by an exposure to substances in the galvanizing department. UNR-Rohn galvanizes parts used to construct broadcasting towers as well as customs products for other companies. Personal breathing zone air samples were collected from individuals who held different jobs throughout the galvanizing department. A total of seventeen personal samples were collected for times ranging between 254 minutes to 517 minutes. The samples were collected on 0.8 micrometer pore size, 35-millimeter diameter, cellulose ester membrane filters using a sampling pump calibrated to an air flow of two liters per minute. The personal air samples were analyzed for zinc, lead, aluminum, cadmium, and elemental chromium using NIOSH Method 7300. Samples were also collected for acid gasses, mists, and ammonia because of the cleaning baths used in the department. The bulk galvanizing kettles were also sampled to verify that the companies MSDSs were correct. Surface wipes were also utilized to evaluate the potential for skin exposure and ingestion. Samples were collected using Wash'n Dri pre-moistened towelettes over 100 square centimeter area. The towelettes were analyzed for zinc, lead, aluminum, cadmium, and chromium using a modification approached of NIOSH Method 7300. Results from the personal air samples showed a range of zinc that was 0.10 to 0.49 mg/m$^3$, which is well below the NIOSH REL. The lead results ranged from trace amounts to 56.1 ug/m$^3$. One of the samples was exceeding the OSHA PEL of 50 uq/m$^3$, while the remaining samples were below the action level. Aluminum results were all less then OSHA PEL and NIOSH REL. All of the cadmium and chromium samples had concentrations that were also below the regulatory limits. The surface wipes that were collected showed levels of zinc that ranged from 5.3 to 331milligrams per square meter of surface wiped, lead levels ranging from non-detectable to 16.3mg/m$^2$, and aluminum concentrations ranging from 0.3 to 72.7 mg/m$^2$. Cadmium was not detected on any of the surface wipes but chromium concentrations ranged from non-detectable to 4.6mg/m$^2$. NIOSH recommended that further studies be conducted to examine lead concentration level of 56 ug/m3. Housekeeping was mentioned to be of concern due to the fact that metal contaminants were present on the surfaces in the area along with the recommendation that people don't smoke in the area due to the risk of ingesting the metal contaminants. Bath levels showed that the MSDS matched those in the bulk tanks. Levels were found to be approximately 102% zinc, 1.15% lead, and 0.05% cadmium. No aluminum and chromium was detected. (Marlow, 1994)

A study was conducted at three hot dip galvanizing plants to determine the employee's exposure to nickel, zinc, and lead. The study looked at dry process plants that used 2% nickel, by weight, in their zinc baths. A dry process means that the steel item is immersed in a zinc aluminum chloride flux tank prior to immersion into the zinc coating bath. A wet process has a flux blanket that covers the bath. The item must pass through the blanket to enter the bath. The dry process tends to create fewer emissions then the wet process. The study collected samples over a three month time period in the summer of 1988. Thirty-two samples were collected during this time and analyzed. Sampling durations ranged from seven to eight hours except for one sample which was conducted during a specific task, approximately 2.25 hours. Area samples were also collected to gather a view point of the overall levels in the plant. The sampling media was a 0.8-um pore size, 37-mm diameter, cellulose-ester membrane filter which was housed in polystyrene cassettes. Personal pumps were attached to the cassettes flowing at two or three L/min. The pumps were calibrated prior to sampling and after sampling was completed. The area sampling was collected at 20 L/min to allow for a larger quantity of air to be collected. The personal samples were collected from a variety of employees performing different jobs. The results of the study concluded that the employee's exposure to nickel was minimal with a peak reading throughout all samples of 0.00037 mg/m$^3$. The area reading for nickel had a concentration of 0.01 mg/m$^3$. The highest personal sample reading for zinc was 1.4 mg/m$^3$ and 0.33 for the area exposure. The highest lead exposure was 0.04 mg/m$^3$. Recommendations were made that even though the levels were low, lead should be looked at more because it is over the OSHA action level. It was also noted that the doors to the shop were kept open during the summer months to help with ventilation, because of this levels may become elevated in the winter months when the doors are closed. Finally they suggested that the baths be completely enclosed with local exhaust for the times they need to galvanize an item. (Verma, 1991)

## Conclusion

The galvanizing process was created nearly one hundred and fifty years and is still a widely used solution to the corrosion. Though the process has evolved slightly over the years, zinc continues to make up the largest portion of the coating mixture. Lead, tin, cadmium, antimony, copper, and aluminum have been added to increase the fluidity, maintain spangle, and increase the adhesion of the coating. These metals are regulated through OSHA due to the potential adverse health effects they have on employees. Employees who are participating in hot work are exposed to several potentially hazardous situations including fumes, toxic gases, and dust. Many studies have been conducted around the hazards of fumes and gases. Zinc oxide has been intensively studied due to the health effects caused be an exposure, metal fume fever. Grinding dust has not been studies as much as fumes and gases but a potential hazard is present. According to literature, grinding must occur prior to welding on coated surfaces to ensure a proper weld is achieved. The grinding activities produce dust which could be placing the individuals at risk. Previous studies have been conducted looking at galvanizing facilities and departments. The results of these studies varied due to the design, size, and ventilation of the area. Elevated lead levels were found along with detectable levels of other trace metals. After the literature review it can be concluded that trace metals could be contained in the zinc coatings and could be release during hot work.

# Chapter III: Methodology

This purpose of this analysis is to determine the current levels of metal exposure, being experienced by employees performing grinding activities on galvanized metal. This chapter explains the selection of subjects, instrumentation used, data collection procedure, data analysis, and limitations of the study.

## Subject Selection and Description

For the purposes of this study, the researcher will conduct all grinding activities himself. The exposure is present throughout the facility and amongst many individuals throughout the industry. The researcher is conducting a single case study. The results/recommendations from this research will be extrapolated throughout the facility.

## Instrumentation

The following tools will be utilized during the analysis. They include:

- Preloaded Cassette, Mixed Cellulose Ester (MCE), 0.8 um, 37mm, 2 piece, Pre-banded filters.
    - Used to collected air contaminants that are present near the employees breathing zone.
- SKC Personal Pump
    - Used to draw air through the MCE at a constant flow rate.
- Bios Defender$^{TM}$ 500 Series DryCal
    - The DryCal will be used to calibrate the SKC pumps before and after sampling.
- AV3000 Scott Full Face Respirator
    - Used to provide fifty times the PEL protection while performing hot-work.
- Tape Measure

  - The tape measure will be used to measure location of employee compared to piece of work and other necessary measurements.
- Dewalt Four and Half Inch Grinder – Model number DW802
  - The grinder will be used to remove the coating from the sampling material.

**Data Collection Procedures**

The researcher will be responsible for identifying and collecting pieces of galvanized metal to be tested. These pieces will be staged in a seventy square foot polyethylene structure. The hot-work will be performed in this structure. This structure represents the "worst" case scenario within the company. An employee performing hot-work in a restricted air flow structure will be presented with higher concentrations of the potentially harmful dust and fumes created by hot-work. The sampling material will be sorted into groups according to the type of application it is used for (i.e. metal grating, I-beams, and flat sheet). Air Samples will be collected using a MCE filter and SKC pump. The pumps will be calibrated before use, utilizing a DryCal with a sample MCE in line. The sampling rate will be set at 4L/min (+/- 5%) and recorded on the sampling data sheet. The MCEs will be placed under the helmet, in the breathing zone of the researcher while the hot-work is being performed. Two samples will be collected simultaneously throughout the activity. Prior to performing the grinding activities, the researcher will be given a full medical test to determine if a respirator can be worn. A medical doctor and occupational nurse will review the results and clear the researcher for a full face respirator. A fit test will then be conducted to determine the appropriate size. A Scott full face respirator will be worn with P100 filters attached. The researcher will grind on each group of materials for one hour while the samples are being drawn. A four and a half inch grinder will be used to remove the coating from the material. A fire watch must be present to comply with company policy and OSHA regulations. The fire watch will remain on the scene thirty minutes after the hot-work has been completed. Each sampling period will be sixty minutes in length. This will provide the lab with sufficient amounts of volume for testing. Between sampling sessions the tent will be aired out for ten minutes allowing the dust from previous samples to settle out or disperse. After all groups of materials have been sampled the pumps will be post calibrated and recorded. The lowest flow rate will be used in the determination of the flow rate throughout the test. The samples will then be shipped to ALS Laboratory for analysis.

## Data Analysis

ALS will analyze the sampling for Panel A metals using the NIOSH 7300/7303 (Mod) method, Appendix B. After the lab analysis is completed the data will be sent to the researcher for comparison against the OSHA PEL requirements. Even if levels are found to be below the OSHA standard or company standard the researcher may suggest improvements.

## Limitations

Throughout the study there will be several methodology and instrumentation limitations.

- The researcher will assume that the structure used in the study is actually the worst case scenario in the field. There may be times where people work in smaller areas, which would create a more extreme environment.
- The materials available for the study are limited to those that are in the scrap yard of Company XYZ. The material used in the study may not directly represent all the types of galvanized metal in the field.
- The researcher is limited in time allowed for the study; therefore a higher flow rate will be used to collect the samples. The flow rate may not represent the actual breathing rate of individuals.

- The structure where the sampling will take place has no ventilation to clear the air between samples. There is a chance that cross-contamination could occur from sample to sample caused by residual dust.

# Chapter IV: Results

The purpose of this study was to identify the current levels of metal exposure that is experienced by employees who are performing metal grinding activities. To complete the study the researcher acted as an employee performing grinding activities on a variety of galvanized pieces of metal. Air samples were collected from within the researcher's breathing zone while the grinding was taking place.

The research questions of this study include:

1. Does galvanized metal contain other heavy metals besides zinc?
2. What are the metals that are airborne while hot-work is being performed on the galvanized metal and at what levels are they present?
3. What are the health hazards to the employees who are performing hot-work on galvanized metal caused by the heavy metal components?

## Summary of Method

As described in chapter three, the sampling was conducted according to NIOSH sampling method 7300 (Appendix A). 0.8 um MCE filters were connected to a SKC personal sampling pump which was calibrated to 4.0 L/min +/- 5%. The researcher performed the grinding activities in a seventy square foot poly shelter. The samples were collected within the breathing zone of the researcher. Samples were collected for one hour (except sample number 1943, which was sampled for thirty five minutes due to a lack of material.) After the sampling was completed the SKC personal pump was calibrated to check the flow rate. The lowest flow rate was used to determine the sample volume. The samples were sent to ALS Laboratory to be analyzed for metals panel A (appendix B). Results were returned to the researcher for comparison against OSHA and ACGIH exposure limits.

A review of literature was performed by the researcher. Documents that were included in the review included industry data regarding the composition of galvanized metal, methods of coating, health hazards of particular metals, and past investigations.

## Results

**Research question #1**- Does galvanized metal contain other heavy metals besides zinc?

A literature review was conducted to identify the chemical make-up of the galvanized metal coating along with the process of coating the metal. The review revealed that zinc is the major component in the coating but other metals could be present. These metals include:

Lead – A common additive to the zinc which aids in the formation of spangle. Lead is also the most common metal found in zinc-containing ore and is carried through the refining process as an impurity of the zinc. Lead also helps to regulate the fluidity of the bathing liquids used in the coating process.

Tin, cadmium, copper, and antimony – All are additive that aid in the creation of spangle on the surface of the coated metal.

Aluminum – Used to increase the adhesion of the coating to the base metal and acts as an inhibitor which reduces the rate of diffusion between the zinc bathing liquid and the immersed metal.

**Research question #2** – What are the metals that are airborne while grinding is being performed on galvanized metal?

Air sampling was used to collect data while grinding was being performed. These samples were analyzed for metal panel A (appendix B). This sampling method analyzes the samples for total dust rather than respirable fraction. Antimony was identified as a potential component of the zinc coating but was not analyzed due to the limitation of metal panel A.

Table 4.1 – Table 4.5 show the results from the metal panels A analysis, only those metals that were identified through literature review to be potential trace metals in the coating are shown. The full results from the analysis are located in appendix C.

The following results show that there is a potential for elevated lead levels when performing the grinding activities. Three of the nine samples presented with levels that were above the OSHA PEL and the ACGIH allowable level. These results are significant due to the regulatory compliance issue as well as the potential for adverse health effects for the employees. The average for the nine samples was calculated using the results without a quantifier, which resulted in an average of 0.0305 mg/m3. 0.0305 mg/m3 is at the OSHA action level of 0.03mg/m3. This is significant because it tells us that if an employee were to grind on galvanized metal in a similar method the likelihood of having a result at or above the action level is 50%.

Table 4.1

Lead Results

| **Sample Number** | Quantifier | **Results (PPM)** |
|---|---|---|
| **OSHA PEL** | | 0.05 |
| **Action Level** | | 0.03 |
| **ACGIH** | | 0.05 |
| **1937** | < | 0.0024 |
| **1939** | | 0.065 |
| **1941** | | 0.028 |
| **1943** | | 0.097 |
| **1930** | | 0.012 |
| **1931** | | 0.064 |
| **1934** | < | 0.0022 |
| **1945** | < | 0.0023 |
| **1935** | < | 0.0023 |
| **Average of samples taken** | | 0.030578 |

The following results show that there is a potential for cadmium exposure. An average of the nine samples was calculated without regards to the quantifier. The calculated average was 0.000821 mg/m3 which is well below the action level of 0.0025 mg/m3. Sample number 1943 was the only sample that had a result (0.004 mg/m3) above the action level.

Table 4.2

Cadmium Results

| Sample Number | Quantifier | Results (mg/m3) |
|---|---|---|
| **OSHA PEL** | | 0.005 |
| **Action Level** | | 0.0025 |
| **ACGIH** | | 0.01 |
| **1937** | < | 0.00015 |
| **1939** | | 0.0011 |
| **1941** | | 0.00038 |
| **1943** | | 0.004 |
| **1930** | | 0.00033 |
| **1931** | | 0.00079 |
| **1934** | < | 0.00024 |
| **1945** | < | 0.00015 |
| **1935** | < | 0.00025 |
| **Average of samples taken** | | 0.000821 |

The results below have indicated that copper has a very low exposure potential. Even though all samples analyzed for copper came back detectable, the levels were very minimal. The average of the nine samples was 0.002243 mg/m3 which is approximately 1/500th of the OSHA PEL and ACGIH levels. Sample number 1943 presented with the highest sample result at 0.0048 mg/m3.

Table 4.3

Copper Results

| Sample Number | Quantifier | Results (mg/m3) |
|---|---|---|
| **OSHA PEL** | | 1 |
| **ACGIH** | | 1 |
| **1937** | | 0.0011 |
| **1939** | | 0.0025 |
| **1941** | | 0.0026 |
| **1943** | | 0.0048 |
| **1930** | | 0.0023 |
| **1931** | | 0.0021 |
| **1934** | | 0.00051 |
| **1945** | | 0.0038 |
| **1935** | | 0.00048 |
| **Average of samples taken** | | 0.002243 |

The following results have indicated that aluminum can be present but at extremely low levels. There is a 50% chance that detectable levels of aluminum will be present during grinding activities on galvanized metals. The results have shown even when aluminum is detected it is at low levels. The highest result was seen in sample 1943 at a level of 0.035 mg/m3. The average of the nine samples collected was 0.046 mg/m3 which is well below the OSHA PEL of 15 mg/m3.

Table 4.4

Aluminum Results

| Sample Number | Quantifier | Results (mg/m3) |
|---|---|---|
| **OSHA PEL** | | 15 |
| **ACGIH** | | 1 (r) |
| **1937** | | 0.013 |
| **1939** | | 0.013 |
| **1941** | | 0.015 |
| **1943** | | 0.035 |
| **1930** | < | 0.012 |
| **1931** | < | 0.01 |
| **1934** | < | 0.011 |
| **1945** | | 0.025 |
| **1935** | < | 0.28 |
| **Average of samples taken** | | 0.046 |

The following results have indicated that detectable levels of zinc can be present during grinding activities. All samples that were analyzed for zinc came back with detectable levels that ranged from 0.32 mg/m3 to 9.7 mg/m3. Sample 1943 had the highest level at 9.7 mg/m3, which exceeds half of the OSHA PEL or unstated action level. The average of the nine samples taken was 4.074444 mg/m3 which is well below the OSHA PEL of 15 mg/m3.

Table 4.5

Zinc Results

| **Sample Number** | Quantifier | **Results (mg/m3)** |
|---|---|---|
| **OSHA**<br>**(Zinc Oxide Dust)** | | 15 |
| **ACGIH TWA** | | 2 (r) |
| **1937** | | 1.6 |
| **1939** | | 5.8 |
| **1941** | | 5.4 |
| **1943** | | 9.7 |
| **1930** | | 1.8 |
| **1931** | | 5.2 |
| **1934** | | 0.95 |
| **1945** | | 5.9 |
| **1935** | | 0.32 |
| **Average of samples taken** | | 4.074444 |

**Research question #3** – What are the health hazards to the employees who are performing grinding activities on galvanized metal caused by heavy metal components?

A literature review was conducted to gather information pertaining to those metals that were identified to be potential components in the zinc coating. The results show that all the metals that could potentially be components of the zinc coating have some level of health effect on human. The following chart depicts the health hazards of those metals.

Table 4.6

Health Hazards of Identified Metals

| **Metal** | Lead | Cadmium | Copper | Aluminum | **Zinc** |
|---|---|---|---|---|---|
| **Health Hazards** | Increased blood pressure, digestive problems, kidney damage, nerve disorders, sleep problems, muscle and joint pain | Cough, chest tightness, substernal pain, headache, chills, muscle aches, difficulty breathing, could potentially be a occupational Carcinogen | Irritation to eyes, nose, pharynx, metallic taste, liver and kidney damage | Nervous system and respiratory issues, impaired lung function and fibrosis | Metal fume fever, chills, muscle ache, dry throat, cough, weakness, blurred vision, low back pain, chest tightness, decreased pulmonary function |

## Discussion

The results of this study indicated that grinding activities on galvanized metal has the potential to exposure the workers to hazardous metals at or near regulatory limits.

A literature review showed that there is potential for small amounts of lead, cadmium, copper, antimony, and aluminum to be present in the zinc coating baths used in the galvanizing process. These metals are used to enhance the adhesion properties of the coating, enhance the appearance of spangle, and increase fluidity of the bathing liquid. Literature also showed that these metals all have the ability to affect the human body primarily the respiratory system. Lead and copper could affect the liver and kidney while cadmium is a possible occupational carcinogen. Using the NIOSH 7300 method as a guide for testing, dust concentrations were evaluated. The results showed that those metals that were identified as possible components of the zinc coating have the potential to become airborne during grinding activities. Lead was the only metal that was present at an average level above the OSHA action level. Cadmium and zinc had a single sample that exceeded the OSHA action level. An observation of the data shows that sample 1943 presented with the highest levels of all five metals. This sample was taken while the researcher was grinding on metal grating. This sample was also the only sample that was collected for less than one hour, it was sampled for thirty five minutes. This data revealed that employees may be experiencing an overexposure while performing grinding activities on galvanized metal.

# Chapter V: Summary, Conclusions, and Recommendations

Nearly 466,000 jobs in 2008 place workers at risk of being exposed to hazards of working with galvanized metals. Metal fume fever is the most prevalent symptom of working with galvanized metal. Individuals at company XYZ are concerned that there may be other hazards that are going unrecognized which are potentially placing employees at risk of over exposures. The purpose of the study was to identify the current levels of metal exposure experienced by employees who are performing metal grinding activities. Grinding activities were selected for the study because it is the first step in preparing the metal for welding. In order to achieve this purpose, three research questions were developed:

1. Does galvanized metal contain other heavy metals besides zinc?
2. What are the metals that are airborne while hot-work is being performed on the galvanized metal and at what levels are they present?
3. What are the health hazards to the employees who are performing hot-work on galvanized metal caused by the heavy metal components?

## Method and Procedures

The tools used to answer the research questions included literature reviews as well as air sampling. Question one was answered using a literature review to gather information pertaining to the components of the zinc coating and methods of coating metal. This information was used to identify those metals that could be components of the coating liquid and to help determine the best way to sample for them during the grinding activity. Question two was answered using the NIOSH 7300 sampling method (appendix A). This method allowed the air surrounding the researcher's breathing zone to be sampled and analyzed for a range of metals (appendix B). The researcher was utilizing a full face respirator for respiratory protection while performing the grinding activities. Samples were collected using 0.8um MCE filters and personal SKC sample pumps. The pumps were calibrated prior to and after the grinding activity, the lowest flow rate was used to calculate the volume of air sampled. These samples were then sent to ALS Laboratories for analysis. Results were sent to the researcher for comparison against OSHA PELs and ACGIH limits. The final question was answered through a literature review. The literature review revealed that all the metals identified as possible components of the zinc coating have the potential to adversely affect humans.

## Major Findings

The analysis of the literature and sample results revealed several concerns. A major finding was that zinc is not the sole component in the zinc bathing liquid. Lead, tin, cadmium, copper, antimony, and aluminum were identified as potential components in the liquid, which is a concern because they have low governmental exposure levels. The second major finding is that lead, cadmium, and zinc are becoming airborne during grinding activities at or above regulatory limits. The nine sample average for lead was at the OSHA action level of 0.03 mg/3 while the highest reading, 0.097 mg/m3, was nearly double the OSHA PEL of 0.05 mg/m3. Cadmium and zinc also had single sample results that were above the OSHA action level. The highest levels were often from the sample that was taken while grinding was being performed on metal grating. This sample was taken for thirty-five minutes, due to a lack of material. The last finding was that all the metals that were identified have adverse effects on the human body. Effects range from respiratory issues to occupational cancer. The recommendation section of this study will provide opportunities to address the issues that were identified through the sampling and literature review.

## Conclusions

Based on the results of this study, the following conclusions have been drawn about employees performing grinding activities on galvanized metal:

- Even though metals may not be shown on the MSDS, because they are at levels less than 1%, results have illustrated that hazardous metals can become airborne during grinding activities.
- The sample results show that lead can become airborne in concentration that are at or exceed OSHA's action level.
- One of the nine samples had cadmium and zinc results that were at or above the action level. It can be concluded that there is possibility that employees could be experiencing an exposure to cadmium and zinc.
- The metals that are components of the zinc coating have the potential to adversely affect human. The hazards ranged from respiratory problems to occupational cancer.

## Recommendations

This study has given the researcher data to make recommendations that would address the issue of exposing employees to metal dust. The following are recommendations for this study:

- Provide local ventilation where employees are performing grinding activities on galvanized metal. The local ventilation would minimize the employee's potential for being exposed to lead, zinc, cadmium, zinc, and other trace amount of metals that are captured in the coating or the base metal.
- Evaluate the possibility of requiring all preparation work to be performed in a shop where ventilation has been installed and the employees can achieve quality airflow. Requiring

all work to be done in shops would remove the potential for confined spaces to become overwhelmed with metal grinding dust. The implementation of this requirement would ensure that all grinding work would be done in a manner that eliminates the inhalation hazards caused be the grinding dust.

- Respiratory controls could be used to increase the levels at which employees could work in. Having employees wear a full face respirator would increase the regulatory limit by 50 times, while supplied air would eliminate any regulatory limits. Company XYZ currently has a respiratory program in place. It would be recommended that the task of grinding galvanized metal be added to the list of tasks that require upgraded PPE.
- Reevaluate the current training program to identify gaps surrounding hazard communication. This training program would help educate the employees on the hazards in the workplace, demonstrate the effectiveness of ventilation, and teach them what kind of respiratory protection should be used. As a result of the training, employees should understand the hazards and also how to identify them before they affect themselves or co-workers.
- In addition to the current medical surveillance employees should be tested for metal components in their blood streams. These tests will provide information pertaining to those jobs that are placing employees at a higher risk for metal exposure. Using these results protective measure can be focus at the identified at-risk groups.
- Consider designing a program that would identify if galvanized metal is the best option for a particular job. Other metals metal may offer a similar level of protection while keeping the employees from experiencing exposures to lead, cadmium, and zinc.

## Recommendations for Further Study

This study was conducted in a very small scale due to the limitation of material, time, and funding. These limitations hindered the amount of samples that were able to be collected and analyzed. The following should be considered for future investigation:

- Perform additional task based sampling on employees who are performing grinding activities. These samples will increase the amount of data points that can be used to draw conclusions thus increasing the statically validity of the study.
- If local ventilation is being used as an engineering control it should be evaluated to confirm that it is adequately removing the dust particles from the employees breathing zone.
- Investigate a potential method for identifying components in galvanized metal prior to work so that a correlation can be drawn between pre-work components and airborne levels. A device such as the Innov-X XRF could be used to identify pre-work components levels. It is a small hand-held device that uses radiation to detect metals that are in surface coatings.
- Develop a sampling plan that would examine a broader range of galvanized metal and the airborne concentration of the grinding dust created. This would increase the ability to draw more definitive conclusions.
- Refine sampling plan to cover specific products or manufactures of galvanized products in an effort to identify specific products that led to high concentrations of metal airborne particulates during grinding.

## References

Agency for Toxic Substance and Disease Registry, Division of Toxicology and Environmental \ Medicine, (1992). Toxicological Profile for Antimony, Retrieved from http://www.atsdr.cdc.gov/ToxProfiles/TP.asp?id=332&tid=58

American Galvanizers Association. (2008). Welding after galvanizing. Retrieved from http://www.galvanizeit.org/aga/designing-fabricating/fabrication-considerations/welding/welding-after-galvanizing/

American Galvanizers Association. (2008). Zinc Coating. Retrieved from http://www.galvanizeit.org/aga/about-hot-dip-galvanizing/what-is-hot-dip galvanizing/the-hdg-coating/physical-properties/zinc-coating/

Barceloux, D. (1999). Zinc. Clinical Toxicology, 37(2), 279-292.

Bydash, J, Kasmani, R, & Naraharisetty, K. (2010). Metal fume induced diffuse alveolar damage. Journal of thoracic imaging, 25(2), 27-29.

Canadian Centre for Occupational Health and Safety, (2002). What are the effects of dust on the lungs? Retrieved from http://www.ccohs.ca/oshanswers/chemicals/lungs_dust.html

Centers for Disease Control and Prevention. (2003). Niosh manual of analytical methods (nmam). ELEMENTS (ICP): METHOD 7300, (3), 1. Retrieved from http://www.cdc.gov/niosh/docs/2003-154/pdfs/7300.pdf.

(2008). Industrial Hygiene Services & Fees. (p.10). Salt Lake City, UT.

Dr. Galv (2002). Controlling spangle - influences. American Galvanizers Association, 60, 17.

El-Zein, M, & Infante-Rivard, C. (2005). Is metal fume fever a determinant of welding related respiratory symptoms and/or increased bronchial responsiveness? a longitudinal study. Occupational Environmental Medicine , (62), 688-694.

Fumes and gases. (2005). American Welding Society, 1-3.

Health hazards of welding. (2009). The Zenith Agriculture.

Hot-dip galvanizing for corrosion protection of steel products. (2000). American Galvanizers Association

Hot work safety procedures (2010). Cornell University

International Zinc Association. (2011). The Spangle on Hot-Dip Galvanized Steel Sheet. GalvInfoNote. 2.6. Retrieved from http://www.galvinfo.com/ginotes/GalvInfoNote_2_6.pdf

International Zinc Association. (2009). Zinc bath management on continuous hot-dip galvanizing lines. GalvInfoNote, 2.4.1. Retrieved from http://www.galvinfo.com/ginotes/GalvInfoNote_2_4_1.pdf

Kiefer CIH, M, Wallace, M, & Sheehy, PhD, J. National Institute of Occupational Safety and Health. (1994). Johnson controls, Inc. (HETA 94-0103-2440)

Labor Occupational Safety and Health Program, University of California. (2003). Welding fumes. Los Angeles

Lindsley, M. (2008). A tale of two coatings, hot-dip galvanizing and zinc-rich paints. Construction Canada, 48-55.

Livelli, G., & Langill, Ph.D, T. (1998). Guidelines for welding galvanized steel. PCI Journal, Retrieved from https://www.pci.org/view_file.cfm?file=JL-98-MAY-JUNE-4.pdf

Marlow BS, D, Seitz CH, T, & , . National Institute of Occupational Safety and Health. (1994). UNR-Rohn manufacturing (HETA 931092-2461)

Merchant, J, & Webby, R. (2001). Metal fume fever: a case report and literature review.

Emergency Medicine, 13, 373-375.

Nims, D. (1999). Basics of industrial hygiene. New York, NY: John Wiley & Sons, Inc.

Organic dust. (2011). [Medical Dictionary]. Retrieved from http://medical-dictionary.thefreedictionary.com/organic+dust

Plog, B, & Quinlan, P. (2002). Fundamentals of Industrial Hygiene. United States: National Safety Council.

Porter, F. (1993). Progress with zinc-coated steel. Anti-corrosion methods and materials, 14(5), 8-12.

Semtrogard, (2002, March 03). Spangle of galvanized metal Retrieved from http://www.sentrigard.com/Files/Technical%20Bulletins/Spangle_SG.pdf

SKC Gulf Coast Inc., Initials. (2011). What is the difference between respirable and total dust sampling?. Retrieved from http://skcinternational.com/kbase/ShowKbase.asp?Article=4301

Steel Mills of the World (2003). The spangle on hot-dipped galvanized steel sheets. GalvInfoNote, Retrieved from http://www.steelmillsoftheworld.com/activities/datacenter/G_Note13.pdf

The National Association of Corrosion Engineers, (2002). Corrosion costs and preventive strategies in the United States. Retrieved from http://events.nace.org/publicaffairs/images_cocorr/ccsupp.pdf

TLVs and BEIs. (2011). Cincinnati, OH: The American Conference of Governmental Industrial Hygienists.

United States Department of Labor, Mine Safety and Health Administration. (2011). Prevention program health topic welding fumes sampling. Arlington, VA: Retrieved from http://www.msha.gov/illness_prevention/healthtopics/hhicm10.htm

United States Department of Labor, Bureau of Labor Statistics. (2009). Occupational outlook handbook, 2010-11 edition,welding, soldering, and brazing worker Washington, DC: Retrieved from http://www.bls.gov/oco/ocos226.htm#emply

United States Department of Labor, OSHA. (2006). Safety and health topics: permissible exposure limits (PELs) Washington, DC: Retrieved from http://osha.gov/SLTC/pel/index.html

United States Department of Labor. OSHA. (2000). Welding, cutting, and heating. Washington, DC: Retrieved from http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=10416&p_table=STANDARDS

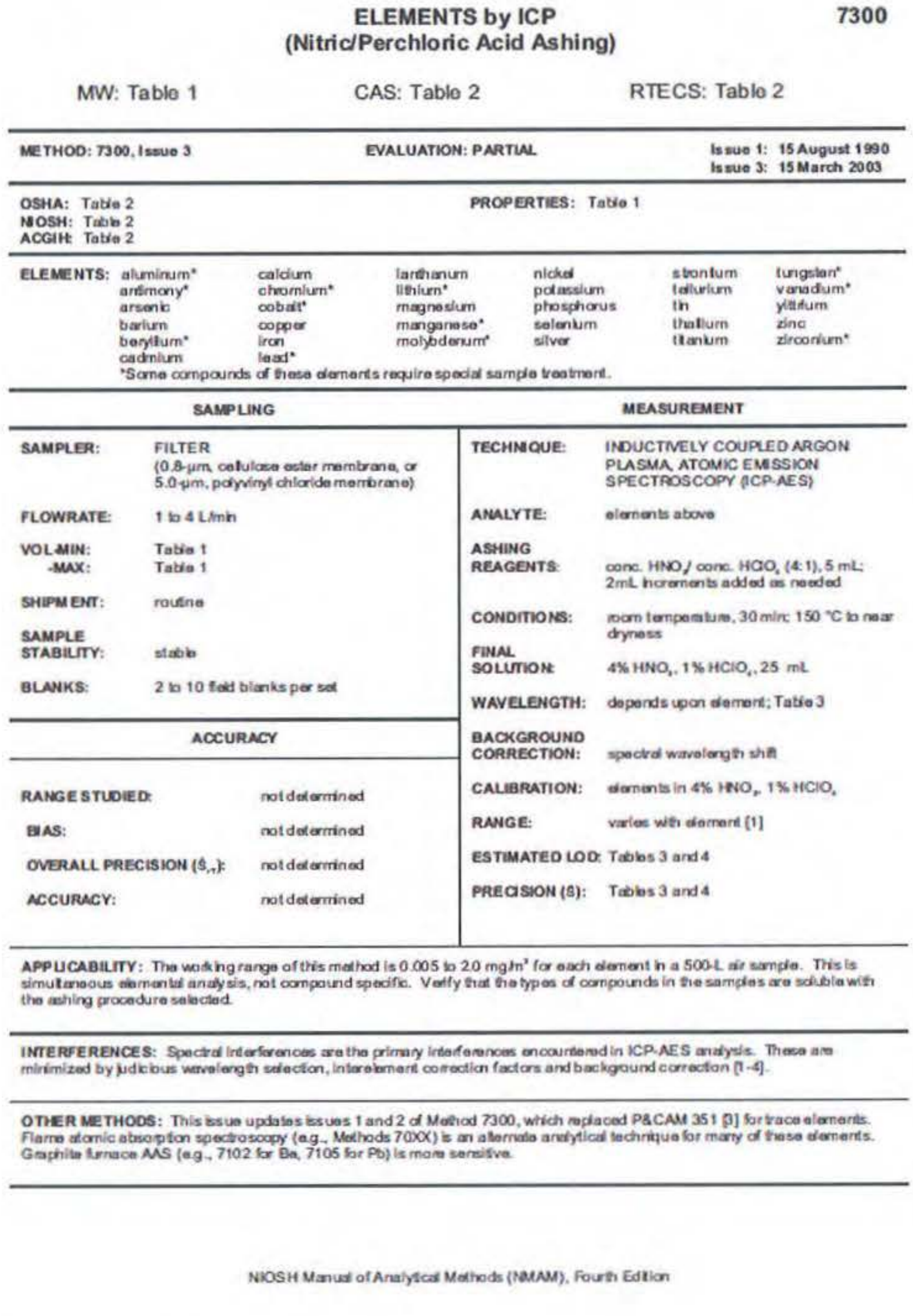
United States Department of labor, Occupational safety and health. (2007). Safety and health topics: welding, cutting, and brazing Retrieved from http://osha.gov/SLTC/weldingcuttingbrazing/index.html

Verma, D, & Shaw, D. (1991). An evaluation of airborne nickel, zinc, and lead exposure at hot dip galvanizing plants . American Industrial Hygiene Association Journal, 52, 511-515.

Welding galvanized steel. (2003). Galvanizers Association of Australia , Retrieved from http://www.gaa.com.au/design_for_galvanizing/design_wogs.html

Zinc coatings. (2006). American Galvanizers Association

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

*Some compounds of these elements require special sample treatment.

| **SAMPLING** | |
|---|---|
| **SAMPLER:** | FILTER<br>(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 ($\bar{S}_r$):** | Tables 3 and 4 |

**APPLICABILITY:** The working range of this method is 0.005 to 2.0 mg/m³ 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

(Centers for Disease Control and Prevention, 2003)

Appendix B – Metal Panel A – Analyte list

**METALS**

| Analyte | Method | Instrument | Medium | Fee($) |
|---|---|---|---|---|
| Metals Panel A (15 Metals) | NIOSH 7300/7303 (Mod) | ICP | MCE Cassette, Swipe, Bulk | 95 |

**Panel A—Analyte list NIOSH 7300/7303(Mod):**

- Aluminum
- Arsenic
- Beryllium
- Cadmium
- Calcium
- Chromium
- Copper
- Iron
- Lead
- Manganese
- Nickel
- Selenium
- Silver
- Sodium
- Zinc

(DataChem 2008)

Appendix C – Complete metal panel A results

| Sample # | | Aluminum | | Arsenic | | Beryllium | | Cadmium | | Calcium | | Chromium | | Copper |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **OSHA PEL** | | 15 mg/m3 | | 0.01 mg/m3 | | 0.002 mg/m3 | | 0.005 mg/m3 | | 5 mg/m3 | | 1 mg/m3 | | 1 mg/m3 |
| **ACGIH** | | 1 mg/m3 (r) | | 0.01 mg/m3 | | 0.00005 mg/m3(I) | | 0.01 mg/m3 | | 2 mg/m3 | | 0.5 mg/m3 | | 1 mg/m3 |
| **1937** | | 0.013 | < | 0.0083 | < | 0.000032 | < | 0.00015 | | 0.049 | < | 0.0021 | | 0.0011 |
| **1939** | | 0.013 | | 0.0085 | < | 0.000029 | | 0.0011 | | 0.036 | < | 0.002 | | 0.0025 |
| **1941** | | 0.015 | < | 0.0076 | < | 0.000029 | | 0.00038 | | 0.053 | < | 0.002 | | 0.0026 |
| **1943** | | 0.035 | < | 0.013 | < | 0.00005 | | 0.004 | | 0.11 | < | 0.0033 | | 0.0048 |
| **1930** | < | 0.012 | < | 0.009 | < | 0.000035 | | 0.00033 | | 0.057 | < | 0.0023 | | 0.0023 |
| **1931** | < | 0.01 | < | 0.0074 | < | 0.000028 | | 0.00079 | | 0.048 | < | 0.0019 | | 0.0021 |
| **1934** | < | 0.011 | < | 0.0076 | < | 0.000029 | < | 0.00024 | | 0.04 | < | 0.002 | | 0.00051 |
| **1935** | | 0.28 | < | 0.0078 | < | 0.00003 | < | 0.00025 | | 0.047 | < | 0.002 | | 0.00048 |
| **945** | | 0.025 | < | 0.0079 | < | 0.00003 | < | 0.00015 | | 0.057 | < | 0.0020 | | 0.0038 |
| **Average** | | 0.046 | | 0.008567 | | 3.24E-05 | | 0.000821 | | 0.055222 | | 0.0022 | | 0.002243 |

| Sample # | Iron | | Lead | | Manganese | | Nickel | | Selenium | | Silver | | Sodium | | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **OSHA PEL** | 10 mg/m3 | | 0.05 mg/m3 | | 1 mg/m3 | | 1mg/m3 | | 0.2 mg/m3 | | 0.1 mg/m3 | | N/A | | 15 mg/m3 |
| **ACGIH** | 5 mg/m3 (r) | | 0.05 mg/m3 | | 0.2 mg/m3 | | 0.1 mg/m3 (I) | | 0.2 mg/m3 | | 0.1 mg/m3 | | N/A | | 2 mg/m3 (r) |
| **1937** | 0.094 | < | 0.0024 | | 0.00057 | | 0.00037 | | 0.0047 | < | 0.00034 | | 0.0096 | | 1.6 |
| **1939** | 0.074 | | 0.065 | | 0.0007 | | 0.00036 | < | 0.0021 | < | 0.00031 | | 0.0047 | | 5.8 |
| **1941** | 0.18 | | 0.028 | | 0.0017 | | 0.0035 | | 0.0072 | < | 0.00031 | | 0.0066 | | 5.4 |
| **1943** | 0.24 | | 0.097 | | 0.002 | | 0.0026 | | 0.0084 | < | 0.00053 | | 0.027 | | 9.7 |
| **1930** | 0.23 | | 0.012 | | 0.0029 | | 0.00088 | < | 0.0024 | < | 0.00036 | | 0.011 | | 1.8 |
| **1931** | 0.069 | | 0.064 | | 0.00079 | | 0.00022 | < | 0.002 | < | 0.0003 | | 0.0078 | | 5.2 |
| **1934** | 0.043 | < | 0.0022 | < | 0.00049 | | 0.0005 | < | 0.0021 | < | 0.00031 | | 0.012 | | 0.95 |
| **1935** | 0.023 | < | 0.0023 | < | 0.0005 | < | 0.00023 | < | 0.0021 | < | 0.00031 | | 0.0082 | | 0.32 |
| **1945** | 0.087 | < | 0.0023 | | 0.002 | | 0.0041 | < | 0.0021 | < | 0.00032 | | 0.0052 | | 5.9 |
| **Average** | 0.115556 | | 0.030578 | | 0.001294 | | 0.001418 | | 0.003678 | | 0.000343 | | 0.010233 | | 4.074444 |