Brush Nickel Plating and Heavy Metal Wastewater Treatment Process Optimization

Major Qualifying Project completed in partial fulfillment
Of the Bachelor of Science Degree at
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Abstract

General Electric Company (GE) at Manchester, Connecticut currently operates a number of machine shops for production and manufacturing of engine parts for aviation industry. The parts are designed as per blue print specifications as requested by companies like Pratt and Whitney, Rolls Royce and others. Production of industrial engine parts requires clean manufacturing and therefore necessitates that the shop also operate a waste treatment facility.

As part of fulfilling the Major Qualifying Project requirement at WPI, the engineering team worked with GE Aviation to optimize two waste treatment processes.

First, a wastewater treatment operation that operates via process of flocculation to separate dissolved heavy metals in water generated from washing engine parts. The company is primarily concerned about reducing titanium and chromium in their wastewater before it can be discarded into the sewers. The engineering team used the method of jar testing to project an optimal amount of polymer used for flocculation and the corresponding pH to maintain for the process. In addition, a considerable amount of research was performed in regards to the use of other polymers for flocculation. Based on cost and data analysis there were five sets of conditions that proved to be optimal for metal removal.

Second, a Nickel Brush Plating process that generates a considerable amount of waste in the process of washing plated parts. As part of recommendations to reduce waste for the process, the group provided the company with two different leads on newer equipment for plating purposes: Sifco Applied Surface Concepts and Liquid Development Company. In addition, the team also provided alternatives to the use of water as a cleaning solution including CitruClean.

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Executive Summary

Proper handling of hazardous wastewater is of vital importance in all areas of industry. Whether the contents of wastewater are oils or heavy metals, this water must be treated and deposited of according to the proper guidelines in order to ensure health for both humans and the environment. Currently, General Electric (GE) Aviation's Manchester, Connecticut facility is working rigorously to improve the efficiency of their wastewater treatment processes. In order to assist in the process, four students from Worcester Polytechnic Institute (WPI) have worked to study the existing systems employed by GE Aviation, while conducting tests and research in order to make recommendations for future improvements.

Two specific systems were studied as a part of this project: the Turbine Exhaust Case (TEC) in Building 3 and the wastewater treatment process in Building 1. The turbine exhaust case involves a relatively small application of nickel plating aerospace parts manufactured at GE Aviation. After each step of the nickel plating process, the part being plated is rinsed with distilled (DI) water, and this rinse contains heavy metals that are hazardous and must be disposed in accordance with state and federal regulations. The group was charged with the task of reducing the volume of hazardous waste produced by the process. In order to work toward achieving that goal, the group conducted research into a variety of alternative plating equipment sets and cleaning solutions in the hopes of finding something that would achieve the desired outcome with more efficiency. As a result of this research, it is recommended that GE Aviation look into purchasing a new nickel-plating system with brush sizes that are more tailored to this process. Another recommendation included separating the draining from the rinsing steps that result in hazardous waste from those that do not contain the harmful heavy metals. Therefore, the hazardous waste volume would decrease significantly. Finally, more closely monitoring the amount of DI waster used to rinse the parts can reduce the overall volume, as well.

The second process that the team hoped to improve was the wastewater treatment system that includes the water used to etch titanium parts. Due to its origin, the water needs to be rid of its heavy metal content before being disposed of. This system includes two reactors which bring the solution to a pH ideal for heavy metal removal and then adds a coagulating polymer to cause the metals to flocculate. The water then travels to a clarifier in which the metal floc settles on slanted metal plates while the water passes through the system. The metal is then collected as sludge and put through a filter press to yield a solid filter cake. While GE Aviation is not in violation of the heavy metal limits in their system effluent, there exists the desire to improve the overall efficiency of the system in order to save the company money. In order to work toward achieving this goal, the group took water samples from the on-site system to test the heavy metal concentrations in the water as it passes through the system to see which step possesses the most room for improvement. It was found that the polymer used to coagulate the heavy metals is being added in excess, which not only wastes company funds, but also causes a potential back-up of the heavy metals in that reactor. Therefore, the group conducted small-scale jar testing on WPI's campus to find the optimum concentration of the polymer that is currently used to achieve the greatest amount of heavy metal removal from solution. Research and testing was also done to see if other polymers or chemicals could act as better coagulants in this system. After extensive testing, it was concluded that the polymer currently being used by GE Aviation is indeed the most efficient; however, the amount of it that is used needs to be much more tightly controlled.

With the recommendations of the group, GE Aviation is equipped with ways in which to advance the efficiency of their wastewater processes. It is the hope that not only are the

recommendations the most environmentally advantageous, but that they also make the most economic sense for the company as it continues to improve its processes and environmental awareness.

Introduction

General Electric Company (GE), at Manchester, Connecticut consists of shop operations that manufacture parts for predominantly aviation customers including, but not limited to: Volvo, Pratt and Whitney and Rolls Royce. The machine parts manufactured by the company include aircraft engine components for various jet engine applications, both commercial and military. As a result of its various processes, GE Aviation-Manchester produces wastewater that requires treatment prior to discharge. Like many other large companies, GE maintains its own wastewater treatment facilities in each building that manufactures such parts.

Metal removal from wastewater has long been a matter of great concern. Industrial wastewaters may contain toxic metals such as lead, mercury, chromium, iron, etc. that can pose environmental hazards if discharged and recycled improperly. As part of a safety measure, the United States government supports policies governing proper treatment of industrial wastewater prior to releasing it into the sewer system or recycling. Complete elimination of metals from wastewater is nearly impossible and is currently not cost effective for many industries. Therefore, regulations exist that govern the maximum concentrations of metals allowed prior to release or reuse.

Companies, like GE, have been historically committed to bettering the environment through research, advancements and new technologies. Even though the company currently meets the Federal and State regulations for discharge of their wastewater, they are looking to make their treatment facilities more efficient. Furthermore, the company is also committed to optimizing the processes themselves and minimizing toxic waste at the end of the process.

The purpose of this Major Qualifying Project (MQP) is to study the wastewater facility located in Building 3 and the brush nickel plating process located at Building 1 of GE's workshops in Manchester, Connecticut. The objectives of this project can be summarized as follows:

1) To develop and implement a plan to reduce process waste from a brush nickel plating operation conducted on a turbine exhaust case and
2) To increase effectiveness and reliability of hydroxide precipitation for metal removal in a wastewater treatment plant.

The wastewater treatment facility in Building 3 currently operates weekly and is responsible for treating all the wastewater generated from plating and finishing within the building. The process makes use of a polymer to coagulate metals prior to being emptied into a clarifier where the metals sink and are collected as sludge. Some of the inconsistencies observed after careful investigations include: poor monitoring and management of the process, discrepancies in the correct amount of the polymer to use, and the overall system inefficiency. Similarly, the nickel plating process in the turbine exhaust case generates waste as a result of inadequate brush usage and an inefficient washing system.

In order to accomplish the objectives highlighted by the company, several experiments were conducted to determine what concentrations of metals exist in wastewater process inputs and the waste generated from the brush nickel plating process. Upon obtaining the results from the wastewater process, several jar-testing procedures were carried out to investigate whether a consistent usage of polymer, both for that currently in use and for new polymers obtained for testing, resulted in increased process efficiency. For the brush nickel plating process, different brush sizes, other plating techniques and more proficient use of other electro-fluids were investigated. After careful research, testing and investigation, guidelines are proposed to the company regarding the optimization of the wastewater process.

Background

GE Aviation

General Electric (GE) consists of seven world businesses: Healthcare, Aviation, Transportation, Corporate, Oil & Gas, Power & Water, and Energy Management. The following GE businesses have sites located in Connecticut, which combined employ about 4,800 people: Aviation, Energy, and Capital. The GE Company's headquarters is also located in Fairfield, CT. GE-Aviation in Manchester, CT consists of five manufacturing facilities covering over 240,000 square feet with 375 employees operating during 3 shifts. GE-Aviation has been in Manchester since 2007 after purchasing Smiths Aerospace. This allowed for over $15 million in new product and over $8 million in equipment for GE-Aviation. Machine parts manufactured by the Manchester campus include but are not limited to combustors, synch rings, turbine exhaust cases, seals, flaps, struts and afterburners. The key processes utilized to manufacture these products include welding, assembly, complex machining, media stripping, laser processing, heat treatment, and thin-wall forming. The Manchester, CT site is ISO 9001/AS9100A certified, as well as NADCAP approved in non-destructive testing, welding, EDM, laser cutting, heat treat, and chemical processing (Sam Cote, 2012, Personal Communication).

Metals of Concern

In industrial processes, the metals which often cause concern in wastewater effluents are chromium, lead, aluminum, cadmium, copper, titanium, nickel and zinc. The environmental and health concerns for each metal are reviewed briefly below.

Chromium

Chromium is a hard, steel-grey metallic element that is listed by the US Environmental Protection Agency (USEPA) as one of 129 priority pollutants. In addition, since chromium is listed as one of the 25 hazardous substances that pose a potential threat to human health, the USEPA views all chromium compounds as toxic or potentially toxic.

Chromium is generally released into the air via combustion processes and released into the water/soil via permitted or accidental discharges from industries. Human exposure to chromium includes inhalation, ingestion, skin and/or eye contact. Chromium is classified by the USEPA as a human carcinogen by the inhalation route of exposure. Chromium exposure causes cellular damage because it is a strong oxidizing agent and can penetrate biological membranes. As a carcinogen, it induces mutations in living cells by damaging DNA-protein, cross linkages as a strong oxidizing agent, and causes high membrane permeability. Inhalation of certain chromium compounds can also cause airway irritation, airway obstruction, and induce lung tumors. Inhalation, as well as ingestion and dermal exposure to chromium have reported renal effects. Chromic acids are powerful skin irritants and can be corrosive to the skin.

Chromium can also be harmful to the environment by causing acidic sandy soil with low organic content. Chromium exposure in water is especially dangerous because it can lead to human consumption (MSDS Chromium, Appendix).

Lead

Lead is a dense, bluish-gray metallic element that was one of the first known metals in human history. Lead is hazardous to the environment because it is not biodegradable; rather it accumulates where it is deposited.

According to the USEPA's Superfund Chemical Data Matrix, lead is one of the compounds with highest toxicity. Lead exposure via inhalation and digestion is released into the blood and distributed throughout the body, being stored primarily in the bones and teeth. Lead poisoning is the leading environmentally induced illness in children, as lead has been known to absorb more readily into young children's bodies than those of adults. Lead poisoning can affect the mental state and physical development as well as reduce attention span in children. Lead causes irritability, poor muscle coordination, and nerve damage to organs in adults (MSDS Lead, Appendix).

Aluminum

Aluminum is the third most abundant element and is extremely chemically reactive. It is soft, durable, and light weight with a silver color. Aluminum is a typically desired metal because of its low density and ability to resist corrosion. Structural components made from aluminum and its alloys are vital to the aerospace industry and other transportation industries.

Aluminum is generally nontoxic (500 grams for an 80 kg person) compared to other heavy metals; however, if aluminum is consumed in high amounts there can be some toxicity. A health concern of aluminum exposure includes reduced skeletal mineralization, while extremely high doses of aluminum can cause neurotoxicity. Aluminum's effects on the environment include causing high concentrations of acid to reduce plant growth because it disturbs root growth and function (MSDS Aluminum, Appendix).

Cadmium

Cadmium is a soft, malleable, white metal that is generally used in batteries, alloys, electroplating, solar cells, plastic stabilizers, and pigments. It is resistant to corrosion and is widely utilized as a protective layer when deposited onto other metals.

Cadmium is a highly toxic metal and exposure to it is known to cause cancer, specifically targeting the body's cardiovascular, renal, gastrointestinal, neurological, reproductive, and respiratory systems. In powder form, cadmium can burn and release toxic fumes. OSHA estimates that about 300,000 workers are exposed to cadmium in the United States specifically in manufacturing and construction industries. The most dangerous form of cadmium exposure is via inhalation of fine dust and fumes, or via ingestion. Cadmium is also a hazard to the environment, due mainly to fossil fuel combustion (MSDS Cadmium, Appendix).

Copper

Copper is a soft, orange colored metal that is known for its high thermal and electrical conductivity. Major applications of copper usage are in electrical wires, roofing and plumbing, and industrial machinery. Environmental exposure occurs mainly from ingestion of drinking water with high concentrations of copper and ingestion of copper salts. Mild forms of copper poisoning can cause nausea, vomiting, diarrhea, and malaise. Severe forms of copper poisoning can also cause pain, hematemesis, and melena (MSDS Copper, Appendix).

Titanium

Titanium is a low density metal with a silver color that is most well-known for its characteristic strong corrosion resistance. Due to its low density, high corrosion resistance, high crack resistance and ability to withstand high temperatures, titanium is widely used to produce lightweight alloys for aerospace components, including jet engines. Titanium, even in high doses, is non-toxic and does not cause any harmful effects to the body. Powdered form titanium can pose a fire hazard, and if heated with air, can cause an explosion hazard (MSDS Titanium, Appendix).

Nickel

Nickel is a corrosion resistant, silver colored metal. Due to nickels corrosion resistance, it is mainly utilized for plating metals. Nickel is popular in the aerospace industry due to its super alloys which are primarily used for jet engines. It is used for making stainless steel and many other corrosion resistant alloys. Exposure to nickel should be kept to a minimum due to the fact that extremely small amounts of nickel can be toxic. Nickel dust can be easily inhaled, and nickel is known for being \ carcinogenic. Nickel sensitivity to the skin is also very common as it causes dermatitis (MSDS Nickel, Appendix).

Zinc

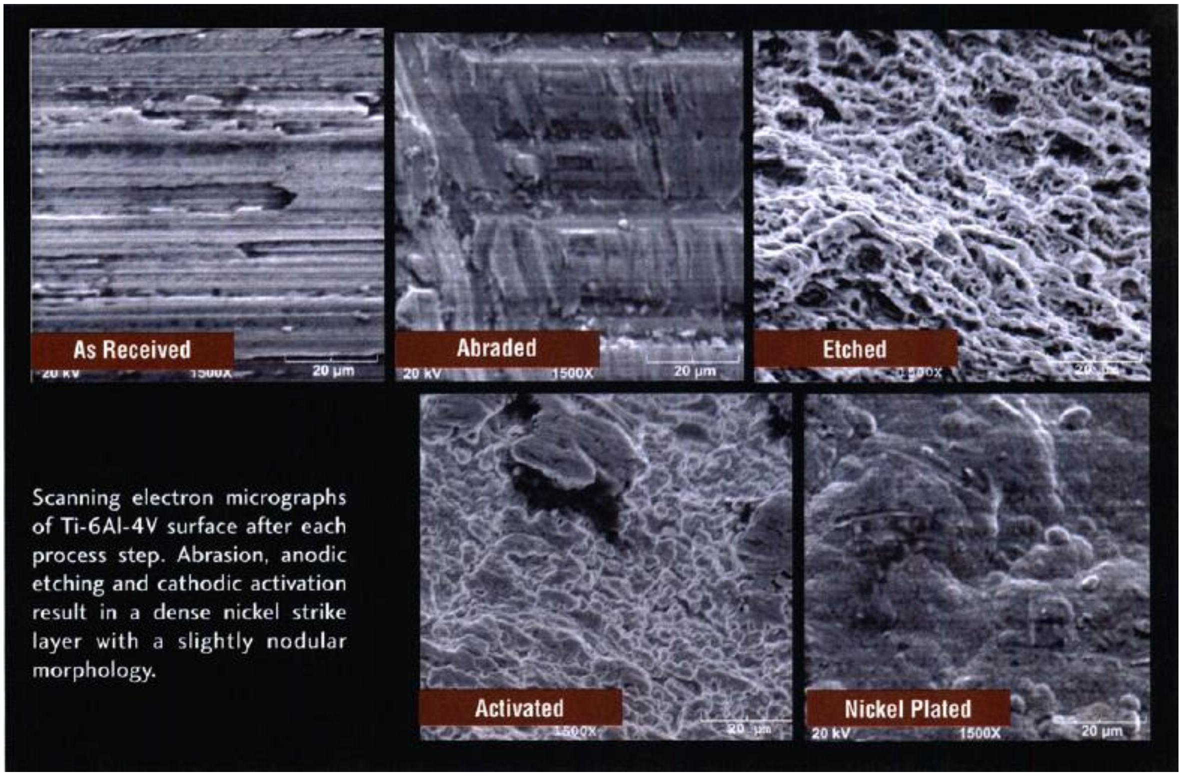
Zinc is a metallic element with a silver-gray color. Applications of zinc include corrosion-resistant zinc plating of steel, batteries, non-structural castings. Zinc is used in making alloys such as brass. Zinc is an essential mineral to the human body that is found in some foods, and can also be consumed as a dietary supplement. Biologically, zinc plays a main role in cellular metabolism – it is required for the catalytic activity of numerous enzymes. Zinc also supports normal growth and is required for proper sense of taste and smell.

Even though zinc is an essential mineral to the human body, excess amounts of zinc can be harmful and cause zinc toxicity. An example of how zinc is toxic is in the stomach lining due to high solubility of zinc in the acidic stomach. In the welding industry, inhalation of zinc can cause zinc shakes, also known as metal fume fever. Extreme exposure to zinc fumes can cause loss of consciousness (MSDS Zinc, Appendix).

Turbine Exhaust Case

Electroplating

High performance equipment is a necessity in the aerospace industry. Aerospace parts are required to withstand friction, high temperatures and corrosive environments while continuing to operate at optimum levels. Nickel is a metal that can live up to those expectations and specifically is used for pre-braze operation, wear resistance, dimensional restoration and corrosion protection because it can be plated with little or no stress added to the surface of the metal. Electroplating an object consists of an electroplating bath solution with one or more anodes. The object is exposed to the solution bath, via a complex current waveform between the anode and the object. The waveform is a cyclic alternating type with two portions – one portion is positive and triangular shaped with one or more spikes and the second portion is negative. The object is then agitated in the bath solution. The figure below displays scanning electron micrographs from an example nickel plating process. First the metal is abraded, and then etched to activate the metal, and finally nickel plated.



Scanning electron micrographs of Ti-6Al-4V surface after each process step. Abrasion, anodic etching and cathodic activation result in a dense nickel strike layer with a slightly nodular morphology.

Figure 1: Nickel Plating Process

Brush plating, also known as selective plating, is a process used to apply localized electroplated deposits and anodized coatings, as well as for electropolishing. While electroplating is used to enhance specific areas on production parts and to correct dimensional errors made in machining and repair shop applications, brush plating can be mechanized or automated and focuses the plating onto only the specific areas that require the coating meaning that the parts do not need to be disassembled and reassembled (Vanek, 2010).

General Electric's Brush Nickel Plating Process

The process for brush nickel plating as performed by GE can be summarized in three different stages: Handling, Preparation and Stripping.

Handling

GE uses a series of brush plating solutions coded as follows: Cleaning Solution BEC 100, Etch & Activate Solution BEC 101, De-Smut Solution BEC 103, Nickel Brush Plating Solution BEC 368 and Nickel Stripping Solution BEC 207. Figure 2 below displays all the solutions used.

Figure 2: Nickel Brush Plating Solutions (from left to right) - Nickel Stripping Solution 207, De-Smut Solution 103, Etch & Activate Solution 101, Cleaning Solution 100

All solutions are kept in a locked cabinet in the braze room and are moved to the site as needed. Each of the solutions has a shelf life of 24 months; upon expiration, they are reported for recall at GE Manchester's calibration system. Some solutions, including Nickel Plating Solution BEC 368, will go through inspection to make sure that the solutions meet the customer and material specifications (Kolyia Gulam, 2012, Personal Communication).

Preparation

Prior to the plating process, all materials being used must be cleaned. After the components are degreased to remove dirt and oil, they are placed in the braze room to prevent contamination. The electro-cleaning solutions BEC 100, 101 and 103 are placed in beakers prior to wrapping cotton onto the cleaning, etch and activate, and de-smut anodes. Similarly the nickel plate anode is covered in cotton and connected to a feed tube and placed into a tank for application process.

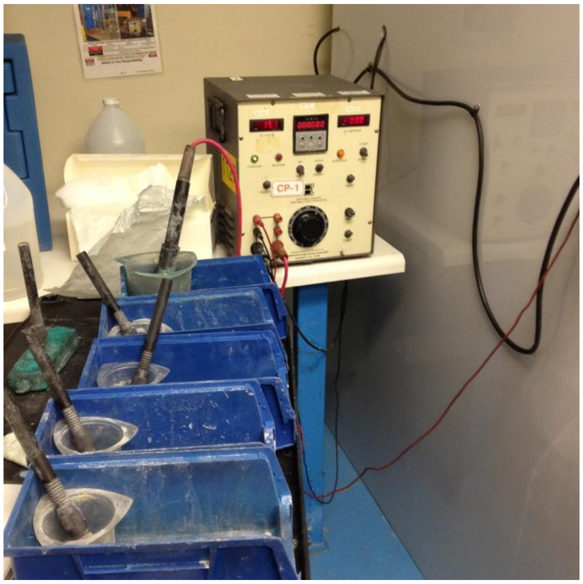


Figure 3: Nickel Brush Plating Applicator Brushes

The application process begins with cleaning with the BEC 100 solution and the electro machine set to 13±2 volts on forward polarity. The process is repeated until discolorations are removed and no water breaks appear. The material is rinsed with de-ionized water and then etched with the BEC 101 solution. The machine is set to 13±2 volts on reverse polarity and the process is done until the material has a "consistent matte or etched appearance." Then the material is de-smut with the BEC 103 solution at 13±2 volts on reverse polarity. This activation step is done until the material will not become any lighter. The appearance of a copper color means that the material was not etched correctly. Etching with BEC 101 must be repeated in such cases. Finally, the material is activated with BEC 101 at 13±2 volts on forward polarity. After each process of etching and activation the material must be rinsed with de-ionized water. It is also important that the anodes and the beakers for each step of activation and etching are not reused.

After etching and activation process is complete, plating is done with electroplating solution BEC 368 at 13±2 volts on forward polarity. The plating time and the entire process are documented accordingly. Figure 3 depicts an example part positioned to be processed.

Figure 4: Part Positioned for Electroplating

After plating is complete the material is subject to stress, burning, peel, and plating thickness tests as required by the company and the customer specifications. Each of these tests follow company procedures as highlighted in GE-Aviation's Work Instruction Manual (Kolyia Gulam, 2012, Personal Communication).

Stripping

Similar to the plating process, the stripping process is done via electro-cleaning with BEC 100 at 13±2 volts on reverse polarity and stripping the nickel with BEC 207 at 13±2 volts on reverse polarity. The change in color is indicative of the metal being removed from the material. After each step, the material is rinsed with de-ionized water. In order to ensure an adequate quarterly test plan, a sample is submitted to the laboratory for destructive testing. The brush plated area is cut by a laser and submitted to an independent lab for adhesion, heat resistance and plating thickness inspections (Kolyia Gulam, 2012, Personal Communication).

Brooktron Plating Solutions

Brooktron Plating Solutions is the current electroplating system that is used by GE-Aviation. These solutions have a very high metal concentration with a fast rate of deposition. The deposit consists of pure metal made out of fine grain structure. The metal is free from porosity and has virtually no hydrogen embrittlement. The metal adhesion contains low stress and metal fatigue. The system is portable and the process can be performed in any environment – research lab, shipyard, machine shop, maintenance department, production line, clean room, etc.

Wastewater Treatment

With increasing attention to compliance with state and federal laws, both global and local companies are turning to wastewater treatment processes to reduce the concentrations of hazardous materials that they release to the environment.

Case Studies

The following case studies of wastewater treatment from around the world point to this topic's expanding importance and various ways in which organizations are combating the problem of environmental pollutants in wastewater.

Treatment of Gold Mine Water

Acid water from gold mines in South Africa contains greater than allowable concentrations of heavy metals. These water streams are treated by precipitation with lime and sulphides. This step is then followed by an ion exchange to reduce the salinity of the water and reduce the anions (sulphate, chloride, bromide, and fluoride) to acceptably low levels. The uniqueness of this process lies in the use of carrier magnetic materials for more efficient separation of water and solids. Oxidation pretreatment is also used to sterilize the water. The benefits of this process include its flexibility and relatively low operating cost. Therefore, although these experiments were conducted on a specific gold mine, the process is worth researching for other waters contaminated with heavy metals and high salinities (Feng).

Heavy Metal Removal by Solid Sorbents

Toxic heavy metals such as copper, lead, and cadmium, have also been shown to be removed from water by metallurgical solid wastes. This process includes the use of bauxite waste red muds and coal fly ashes acting as sorbents. In these experiments, metal uptake (sorption) and release were investigated by thermostatic batch experiments. The distribution ratios of metals between the solid sorbent and aqueous solution were found to be a function of sorbent type, equilibrium aqueous concentration of metal, and temperature. These heavy metal-loaded solid wastes may then be solidified by adding cement to create a durable concrete mass that will ensure safe disposal. These results support the argument that one can treat one industrial plant's effluent with the solid waste of another (Apak). While this would reduce the cost of the water treatment process, it would not necessarily reduce the amount of solid waste produced by the combined system.

Biological Processes for Wastewater Treatment

Biological processes are also being researched for the treatment of heavy metals in wastewater streams. While microorganisms cannot destroy metals, they can influence metals' mobility by modifying their chemical and/or physical characteristics. Only one system using microorganisms to remove metal from liquid wastes has been commercialized in the past 25 years; therefore there is still a lot of development to go in this area of wastewater treatment (Eccles).

Electrocoagulation as an Alternative to Chemical Precipitation

The option of electrocoagulation was studied for the removal of heavy metals from acidic soil leachate at a laboratory pilot scale. It was evaluated via an electrolytic cell using mild steel electrodes. After experimentation, it was determined that electrocoagulation was as effective as chemical precipitation for removing metals having low contamination levels. In fact, cadmium was more effectively removed by electrochemical treatment. The one exception was nickel, which was better removed by chemical treatment. The main benefit for this system is that its cost including energy, chemical, and the disposal of metallic residue was up to five times lower than what was recorded using chemical precipitation (Meunier).

Water Treatment in Industry

In several manufacturing processes in industry, there are wastewater streams that must be treated to below regulatory levels/limits per permit issued to the industry before they can be discharged. These wastewater streams often contain oil, grease, and/or heavy metals depending on the type of manufacturing that is taking place. In systems in which the final products are metallic in nature, the main concern is the removal of heavy metals that enter the treatment process in a stable, dissolved aqueous form and are unable to form solids, making the wastewater hazardous. Common heavy metal contaminants include arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc (Armenante).

The goal of waste water treatment in industry is to make it so that the metals will form insoluble precipitates that can be easily removed, and the water with now low metal concentrations can be discharged having met regulatory limits. Metal precipitation is primarily dependent upon two factors: the concentration of the metal and the pH of the water. Metals are usually present in quantities of 1-100mg/L and at neutral or acidic pH values (<7). These are unfavorable conditions for metal precipitation; therefore, caustics must be added to the water to cause the metals to form solids that can be precipitated (Ayres).

After the pH is brought to favorable conditions, the next step of many industrial wastewater treatment plants includes rapid mixing that mixes the metal particles with a coagulant to promote settling. This mixture is then fed to sedimentation tanks with a pH of about 9.0 for 1.5-3 hours where no mixing happens, allowing settling to occur. Water from the sedimentation tanks then goes to a filtration unit to catch any of the particles that did not settle. The solids produced in the sedimentation stage are called sludge and must be handled in accordance with federal guidelines (Ayres).

The Use of Hydroxide in Wastewater Treatment

In wastewater treatment processes, it is not uncommon for chemicals to be used for treatment. Commonly, hydroxide is utilized to raise the pH of water. When in the form of sodium hydroxide, or caustic soda, a product results that can have a desired strength ranging from a concentration of 2% to a maximum of 50%. When applied in wastewater treatment, a hydroxide can neutralize the pH of the acidic product and/or separate a metal precipitant.

When hydroxide is used in the precipitation process, a series of steps will ensure the most product of precipitate. Ideally, the incoming solution is pH adjusted to the optimum range for making a hydroxide precipitate. In industry, it is understood that the wastewater precipitation system will operate allowing enough time for a low flow and the liquid will naturally settle. Commonly, a lamellae plate clarifier with plates set 1” apart will force the water to run through the channels at a 45 degree angle. The solids accumulate on the plates and will fall off into a different sump.

Sometimes in the hydroxide precipitation process, a sulfide will be used to lower the solubility of the solution. Though this method will help the precipitate come out of the solution, it will not always be effective. If the precipitation does not occur with or without the sulfide it is possible that the flow is too high for the settling to occur or a polishing system might need to be added to the end of the system. Chelates, an organic compound that holds metal in solutions at a high pH, can also effect the precipitation. Hydroxide precipitation depends on the insoluble metal hydroxide forming and if the chelate impairs this, there will be no reaction. The addition of sulfide or another strong reducing agent will break weak chelates, or the substitution method can be utilized. If a non-hazardous metal is added that the chelate prefers more than the metal, both will form. In hydroxide precipitation, it is important to consider all factors of the solution before determining the success of precipitation.

The Use of Polymers in Wastewater Treatment

In wastewater treatment, polymers are used to suspend solids to produce large amounts of floc, or solid material. A polymer is classified as a large organic chain of molecules with positive or negative charges. Each polymer chain can be a different length, consisting of millions of monomer units. Polymers are unique in the way that they are extremely diverse, allowing for many possibilities and options in wastewater treatment. Polymers can be in many physical forms, hold varying charges with several charge densities, and even have different molecular structures.

Polymers used for flocculation are generally available in three different configurations: cationic, anionic and nonionic. Some of the commonly used polymers in industries are listed in Table 1.

Table 1: Polymers Commonly Used in Wastewater Treatment

Cationic	Anionic	Nonionic
Polyacrylamide Polyamines Polyvinylpyridines	Polyacrylic Acid Poly Vinyl Sulfonic Acid Poly Styrenic Sulfonic Acid	Polyacrylamide Poly Ethylene Oxide

Generally speaking, anionic polymers are mostly used for wastewater containing inorganic compounds, whereas cationic flocculants are used for organic compounds. The configuration for treating wastewater is dependent on the amount and type of chemicals present in the water being treated. The mechanism in which the flocculation works is determined by several physical and chemical parameters including the molecular weight, the particle charge, porosity, reactivity etc. Polyacrylamide and its variations are one of the biggest marketed products for wastewater treatment. There exists a large market for manufacturing of polymers for wastewater treatment purposes. These companies make polymers with specific configurations and sell them under brand names.

Polyethylene glycols (PEGs) are often used in chemical industries as surfactants and defoamers. The team picked the polymer to observe if the dissolved chemicals would collect on the surface in the presence of the polymer. PEG is generally available in different ranges of molecular weights and different mediums. From a considerable amount of literature research on other polymers, the team chose to obtain the chemical in a liquid form with a specific molecular weight. In addition to testing for flocculation and sludge formation, the team decided to observe other mediums for collecting dissolved metals from the wastewater.

Literature research and information from water-treatment specialists also suggest that flocculation in wastewater might work best in the presence of more than just one polymer. In order to test for this, the team decided to mix two and three polymers in different proportions with a different range of pH.

Safety in Wastewater Treatment Plants

In industry, safety comes first – a safe and healthy environment is the most important thing that a company can offer their employees. Along with many other manufacturing safety precautions, wastewater treatment has additional safety concerns. The major facility safety categories can be identified in three major areas: confined-space entry, referring to an area which is enclosed with limited access which makes it dangerous; lockout/tagout; and personal protective equipment.

Confined-space entry is a major concern in wastewater facilities because of the constant monitoring and touch of the systems. Locations in the facility that are of concern to be cramped are the aeration basins, digesters, applicator machines, primary tank, manholes, and vaulted sampling pits. Many of these locations are indicated as a concern because they are typically below ground level on site and use stair entry for access. The frequency of touch time on this equipment is necessary for routine maintenance, inspection testing and repairs. Though the level of precautions is specific to each plant and depends on the layout, some general guidelines can be followed. For fall protection, personal harnesses, ladder-safety systems, tripods, and hoists are important to consider for safety of those working on the equipment. In all cases, OSHA guidelines should be followed. For all safety concerns, it is important that all equipment and signs are marked well and updated as changes in the area occur. In treatment facilities, it is also important to monitor the air quality, ventilation, respiratory, and fall protection in order to ensure good health and safety for all involved.

Another important area of safety to consider on machines that is currently worked with for maintenance, operation, and repair is the lockout/tagout system. This system ensures that energized equipment is de-energized or shut down, locked out, and tagged before a person can work on it. Some equipment that is particularly important to use this system with is pumps, electrical motors, values, and mixing systems. The valves and pipelines should also be considered because of the dangerous potential of water entry and high pressure. Personal protective equipment (PPE) helps employees ensure their health and safety while on the job. All employees and visitors at a wastewater treatment facility should be wearing safety glasses, face shields, hard hats, gloves, safety shoes, and if necessary, chemical-protective clothing. This is to ensure personal wellness in day to day activities as well as an accident free facility. Finally, a shop floor should identify stretches and routines for operators to complete in order to improve ergonomics (OSHA Law & Regulations, 2012).

Government Regulations

GE-Aviation has permits that allow for 23,000 gallons per day average flow and 25,100 gallons per day maximum flow as deemed by the state of Connecticut. Average monthly limits, maximum daily limits, and instantaneous limits are also set for the contaminants listed in Table 2. In Connecticut, the nickel limits are high and, therefore, nickel is not considered hazardous at the levels with which GE operates.

Table 2: Connecticut Wastewater Heavy Metal Limits (State Permit)

Metal	Average Monthly Limit (mg/L)	Maximum Daily Limit (mg/L)	Instantaneous Limit (mg/L)
Cadmium	0.1	0.5	0.75
Chromium	1	2	3
Cyanide	0.65	1.2	1.8
Lead	0.1	0.5	0.75
Silver	0.1	0.43	0.75

A permit holder must also follow compliance conditions in order to be in good standing with the state. Non-compliance can be issued if 66% or more of all measurements taken during a six-month period exceed the average monthly or maximum daily limit for the same pollutant parameter. Those in which 33% or more of all the measurements for each pollutant parameter taken during a six-month period equal or exceed the average or maximum daily limits multiplied by 1.4 for BOD, TSS, oil and grease or 1.2 for all other pollutants except pH will be in non-compliance. Any discharge of pollutant that has caused imminent endangerment to human health, welfare, or to the environment will not be tolerated (Hazardous Waste Regulations, 2012).

General Electric's Wastewater Treatment Process

GE-Aviation in Manchester, CT employs a conventional flow-through, hydroxide precipitation system in Building 3 to process the wastewater from their alkaline and acid clean, as well as their abrasive tumbling operations. The system involves equalization, pH adjustment, precipitation, and clarification/settling to remove heavy metals and other contaminants. The system also includes a collection of pumps to transfer the wastewaters from lift stations within the cleaning areas (Mike Delaney, 2012, Personal Communication).

System Influent

Titanium Acid Cleaning

Titanium parts are sent through a cleaning solution consisting of nitric acid and ammonium bifloride which solubilizes the titanium substrate in the solution. This solution is segregated from the rest of the wastewater in a strong acid dump tank. The dump tank has a maximum volume of 700 gallons. Water rinsing after titanium cleaning is performed in overflow/underflow hot and cold rinse tanks. This water is then fed to the wastewater rinse lift station located behind the acid clean line. Typical rinse water flow from the acid clean line is 3-4 GPM during part processing (Mike Delaney, 2012, Personal Communication).

Alkaline Cleaning

The 1300 gallon alkaline cleaning tank is dumped manually into a 1500 gallon alkaline dump tank. This solution is then added to the equalization tank. This solution is dumped monthly due to oil, grease, sediment, calcium, and/or chloride contamination. Water rinsing after alkaline cleaning is performed in overflow/underflow hot and cold rinse tanks. Typical rinse water flow from the alkaline clean line is 4-6 GPM during part processing (Mike Delaney, 2012, Personal Communication).

Figure 5 displays the lift stations for the wastewater treatment line including the equalization tank in the middle and the acid dump tank on the right.

Figure 5: Wastewater Line Lift Stations

Process Flow

The system runs automatically, neutralizing and precipitating the solids; however, the operator should monitor the pH settings and the flocculated solids in the clarifier. Preventative maintenance checks should be performed regularly for system safety and reliability. Operators should also comply with the “Daily Wastewater Treatment Walkthrough Checklist” (Appendix A).

pH Reactors

Wastewater from the influents described above is fed to a series of pH reactors. The 400 gallon polypropylene reactor has caustic metering pumps to adjust the wastewater to a pH of 8.5-9. The typical retention time at the maximum feed rate of 10 GPM is 40 minutes with a working volume of 350 gallons. There is a second reactor similar to the first, except the second includes the addition of calcium chloride from a pump activated by the system during wastewater processing. Feed rates for calcium chloride addition are set to add approximately 400 mg/L to the wastewater. Figure 6 displays the six pumps used for pH neutrality, as well as the polymer to be added.

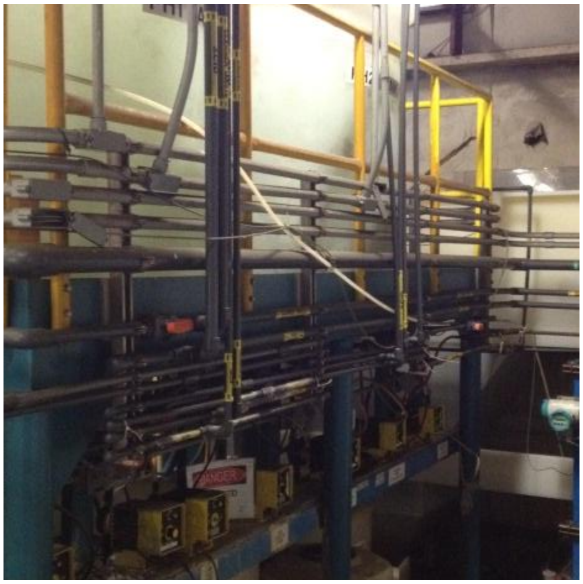


Figure 6: LMI Pumps

This step is instrumental in breaking the chelated structure of the metals to enable precipitation. 50% sodium hydroxide and sulfuric acid are added to the system at both the first and the second pH reactors. Figure 7 displays the current pH tanks in the process (Mike Delaney, 2012, Personal Communication).

Figure 7: pH Tanks

Flash Mix Tank

The wastewater from the second pH reactor is fed to a 115 gallon flash mix tank used to rapidly mix an anionic liquid polymer solution. The dosage of polymer should be minimized to the best clarity of the effluent and adjustments made with the polymer supplier as needed. The mixer is run at approximately 33 Hz. The addition of the polymer helps to increase the size of the precipitate, which decreases the settling time (Mike Delaney, 2012, Personal Communication).

Flocculation/Clarifier

From the mixer, the wastewater is fed at approximately 10-12 GPM to an inclined plate clarifier with an integral flocculation chamber that serves to flocculate and gravity separate the precipitant. The slow-mix flocculation chamber is the first step in this unit, and it is run at 15 Hz. The inclined plate clarifier is designed to accommodate 30-40 GPM, depending on the settling rate. Sludge collected from this process is pumped into the sludge thickener tank. The pump rate is adjusted as needed based on the amount of solids settling. This is a place in the process that is used for sample collection using an automated refrigerated composite sampler controlled by a water flow meter. Figure 8 displays the clarifier that is currently being used (Mike Delaney, 2012, Personal Communication).

Figure 8: Clarifier

Sludge Thickener

The wastewater is then fed to a 1500 gallon coned bottom polypropylene sludge thickener tank. Three decant valves are installed in the side of the tank to drain wastewater to the decant lift station (Mike Delaney, 2012, Personal Communication).

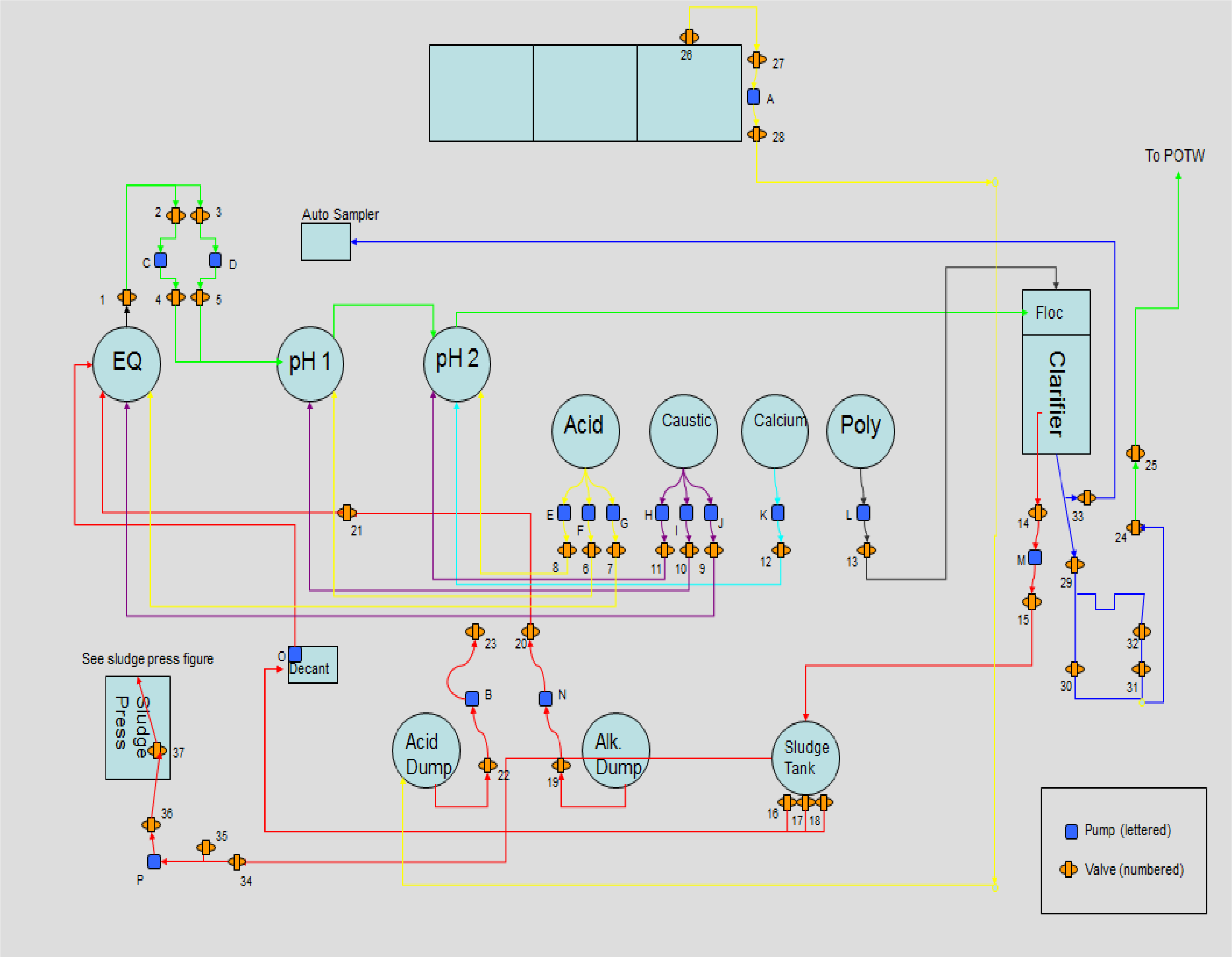
Filter Press

Next in the system is an air over hydraulic filter press used to process treatment sludge. Waste filter cake from the press is classified by the EPA as F006. Filtrate from the filter press is discharged to the decant lift station, which pumps back into the equalization tank. An air blow is conducted after the filter press is full and filtrate is removed to further dry the sludge prior to off-site shipment (Mike Delaney, 2012, Personal Communication). Figure 9 shows the filter press used in house.

Figure 9: Filter Press

Final Monitoring

A flow meter and pH meter are located prior to the discharge point where the treated water is released to the sewer. The system will disable should the pH be out of the range of 6.5-9.5 (Mike Delaney, 2012, Personal Communication). The flow diagram of the entire system can be viewed in Figure 10.


EQ
pH 1
pH 2
Acid
Caustic
Calcium
Poly
Floc
Clarifier
Auto Sampler
To POTW
Acid Dump
Alk. Dump
Sludge Tank
Decant
Sludge Press
See sludge press figure
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Pump (lettered)
Valve (numbered)

Methodology

Turbine Exhaust Case

The brush nickel plating process is much smaller in scale compared to that of the wastewater facilities. Prior to designing a process that is optimized and efficient; several tests were carried out on fluids used in the process to determine the concentrations of metals washed out. The etching and activation solutions were also tested to determine the amount of metal etched out of the parts prior to plating. Some of the areas of concern observed upon initial observation include the geometry of the brush and the efficiency of the plating process in general. Therefore, research was conducted into alternative suppliers for this equipment.

Wastewater Treatment

Sampling from On-Site System

In order to determine the concentrations of hazardous heavy metals in the wastewater treatment system, analysis of samples had to be conducted. To begin, samples were taken from various places in the on-site system in order to track the variance in composition of heavy metals in the water throughout the process. Water samples were drawn by hand from the Equalization Tank, pH Reactor 2, and the Clarifier. While the samples were being taken, it was important not to gather any solid waste samples with the water that could alter our test results. The samples were placed in plastic sample vials preserved with HNO_3. A sample of the solid filter cake waste was also gathered. These samples were sent to be tested for the following heavy metals through an Inductively Coupled Plasma (ICP) analysis: aluminum, cadmium, chromium, lead, copper, nickel, titanium, and zinc. The heavy metal of particular interest is titanium because the acid tanks that feed the wastewater system are used to etch titanium parts. The concentrations of cadmium, chromium, and lead are typically undetectable; therefore, they will only be included in the group's initial sampling analysis.

A second set of samples was taken, as well in order to test the heavy metal levels for consistency. For these tests, samples were taken from the Equalization Tank (half full, 1500 gallon), pH Reactor 1 (full, 400 gallon), pH Reactor 2 (4/5 full, 400 gallon), and the Clarifier (full).

On-Campus Testing

Current Polymer

The current polymer used for coagulation in the wastewater process is anionic polyacrylamide – F-300. It is supposed to be used in a 50-100mL polymer/50L water dilution. However, due to a lack of measurement by the operators, this is usually not the case. During our initial testing, our sponsor said that it appeared like the polymer solution that was being used was over concentrated due to its thick consistency. Therefore, the group decided to conduct small-scale jar testing in the laboratory at Worcester Polytechnic Institute (WPI) in order to study the effects that the concentration of the polyacrylamide has on the coagulation of the heavy metals in the wastewater. In order to conduct the testing, wastewater samples were taken from pH Reactor 2 of the Building 1 wastewater treatment system. The group also brought enough of the non-diluted anionic polyacrylamide and caustic 50% sodium hydroxide (balance water) to perform the tests. The final chemical supplied from GE was calcium chloride flake, which is dissolved in water and added to the mixture to neutralize the pH before the polymer is added.

The first tests that the group decided to run were with the currently recommended concentrations of the existing polymer recommended by GE. Keeping the tests small-scale with 200mL of wastewater, the group ran tests using 3, 2, 1, 0.5, and 0.25mL of polymer. These values fell within the recommended 50-200mL polymer/50L water concentration with also going above and below a bit to search for the optimum. These tests were first conducted at a neutral pH. The first step in one of these tests was to measure 200mL of the wastewater from GE using a graduated cylinder and then pour it into a 400mL beaker, allowing it to mix on a stir plate at high speed. A litmus strip was used to test the initial pH of the sample. Subsequent pH tests were taken after each chemical was added to the mixture. Next, the sodium hydroxide was to be added in order to achieve the desired pH (for this initial set of tests, the desired pH was 7, so no caustic needed to be added). Then, approximately 3.994g of the neutralizing calcium chloride flake was dissolved in 100mL of water. These amounts were used in order to match the 50lb calcium chloride/150 gallons water concentration used by GE. This solution was allowed to mix at high speed until all solids had been dissolved and then added to the wastewater and NaOH mixture.

Figure 11: Mixing Calcium Chloride Solution

The desired amount of polymer was then added using a micropipette. Once the polymer was added, a stopwatch was started. After three minutes of mixing at a high speed, the speed was slowed and the mixture was stirred for an additional two minutes.

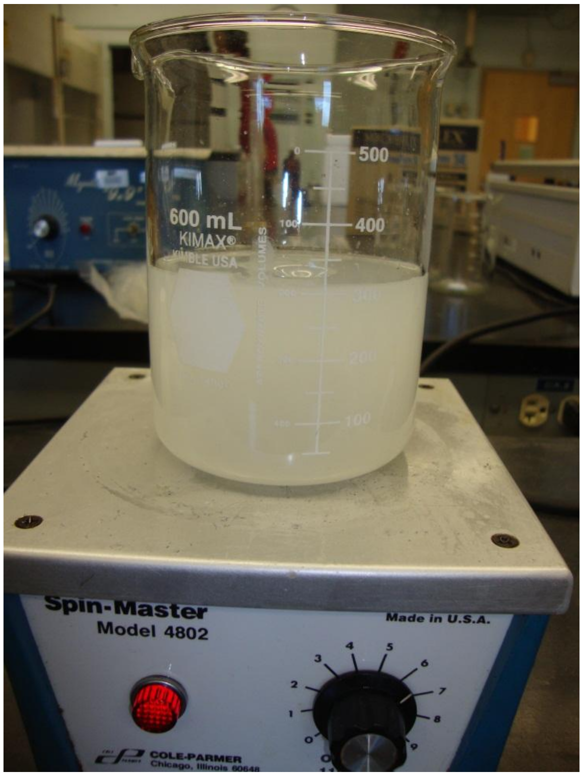

Figure 12: Example of Jar Test in Progress

Observations were then made as to the amount of flocculation of heavy metals. This procedure was repeated for all of the concentrations of polymer mentioned above.

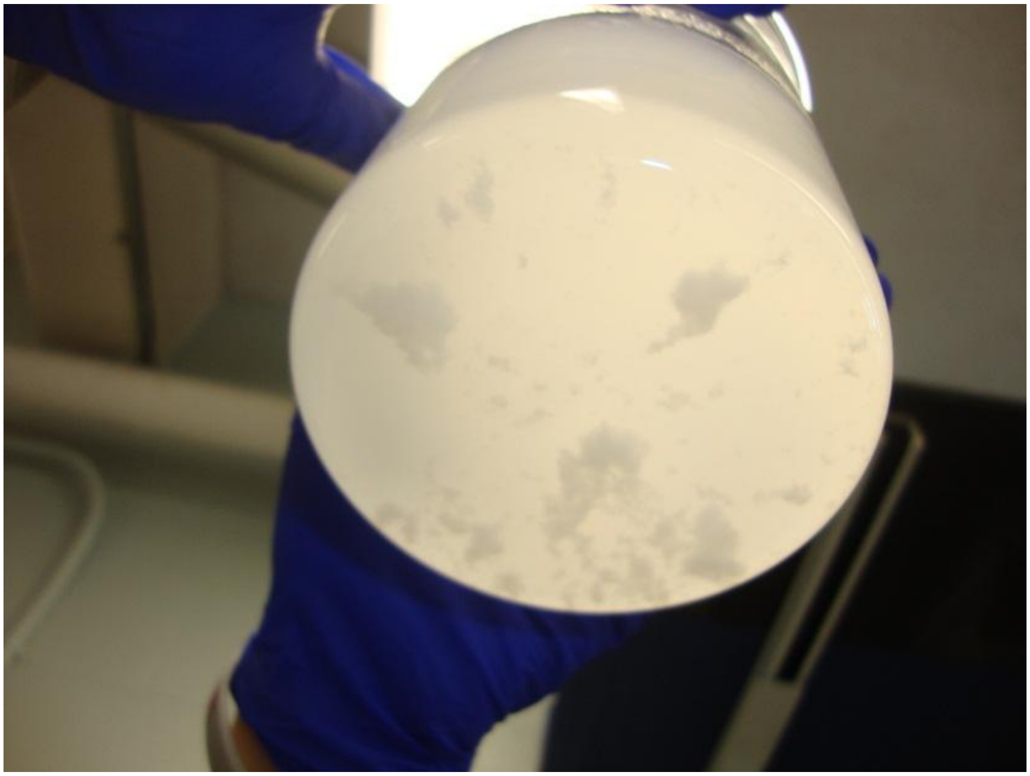

Figure 13: Example of Post-Jar Testing Flocculation

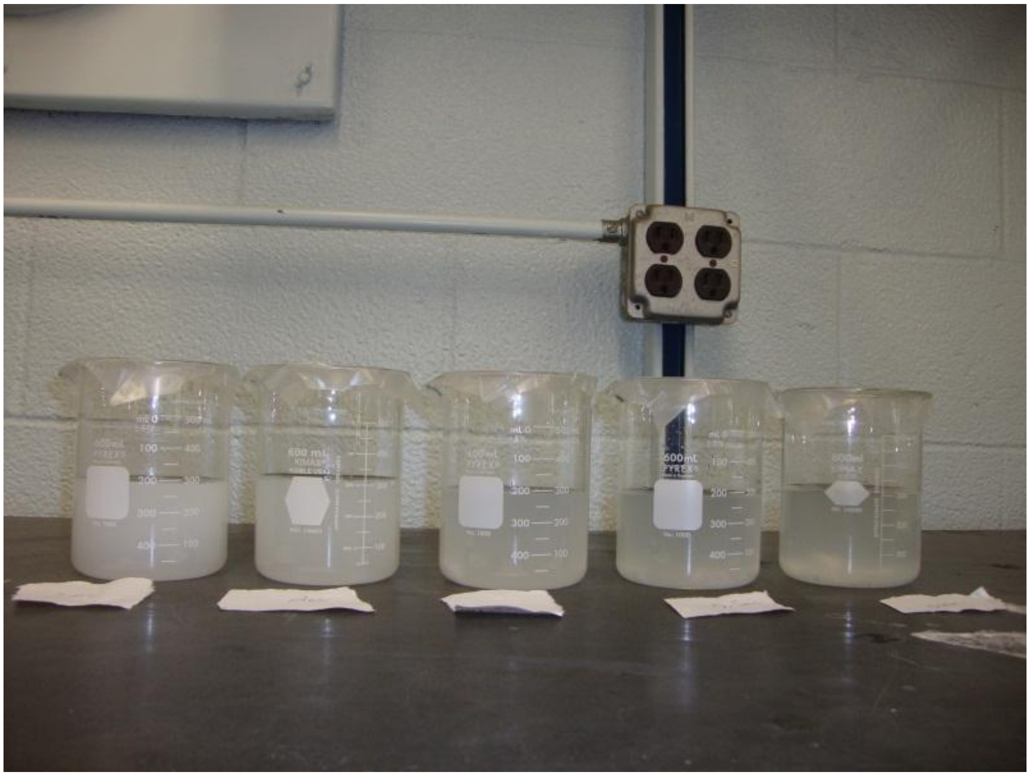

Figure 14: Base Cases Post-Jar Testing

Once this base set of tests was run, the group experimented with the amount of NaOH that needed to be added to the solution in order to achieve the pH recommended by GE of 8.0 to 9.0. It was determined that, in most cases, adding 0.01mL of a 10% NaOH solution achieved a pH of 8 and 0.02mL of a 10% NaOH solution achieved a pH of 9. The group ran jar tests per the same procedure as above. However, the 3mL of polymer concentration was removed from the list of tests because of the poor flocculation observed in comparison to the other polymer concentrations in the previous set of tests.

In order to add quantitative analysis to our qualitative observations as a way of evaluating our jar testing experimental results, the group decanted off the water from the flocculated heavy metals and stored the water in sample bottles. This water was sent for ICP testing at GE to see the amount of heavy metal left in the water after the polymer coagulation step in the wastewater treatment. This was indicative of which concentration of polymer at which pH is the best for stripping the water of heavy metals.

Experimental Polymers and Chemicals

In addition to the anionic polyacrylamide used by GE, the group decided to test other polymers used for wastewater treatment to see if there are better options available that could increase efficiency and perhaps save the company money. A variety of polymer literature was studied in order to select polymers that aid in heavy metal flocculation in wastewater. After careful consideration, the following polymers were chosen for testing.

Polyacrylonitrile

The first alternative polymer tested was a 50% polyacrylonitrile solution. This polymer was tested using the same procedure for jar testing described above with 0.25, 0.5, 1, and 2mL or polymer. Each of these concentrations was tested at a pH of both 8 and 9. The decanted water from these tests was sent for ICP testing, as well, to see how this new polymer compared to the one already used by GE.

Hydrogen Peroxide

Hydrogen peroxide has gained great popularity in chemical wastewater treatment in recent years. The safety and ease of use of the product made it a perfect candidate for testing. In addition to its versatility, it is also one of the most powerful oxidizers with a high reactivity. However, there exist very few studies regarding the optimization of the chemical for wastewater treatment. Therefore, there are a number of constraints that might affect the results in flocculation including maintaining an adequate pH balance, temperature control and variation, stirring, settle-time and others.

Polyethylene Glycol

Polyethylene glycol (PEG) has been used in industrial water treatment for a number of years now. An aqueous solution of PEG with a molecular weight range of $1*10^5$ to $5*10^6$ was chosen for testing purposes based on recommendations in literature. Similar to hydrogen peroxide, the PEG might work best with a perfect pH and settle-time.

Poly (4-styrenesulfonic acid-co-maleic acid) Sodium Salt Solution

Polystyrenic sulfonic acid (PSSA) and its salts are also used in treating wastewater. PSSA has been used in applications including flocculation and sludge disposal for a long time in industries. Unlike the other two products above, this polymer works best with flocculation of specific heavy metals. The optimum molecular weight of the product must be taken into consideration for optimal flocculation. The anionic configuration of PSSA – available as a sodium salt solution – was chosen for testing.

Polymer Mixtures

Following testing of each polymer individually, a combination of polymers was experimented with together to see the effect mixing polymers would have on the flocculation rate of the wastewater. One combination performed was 0.01mL of anionic polyacrylamide and 0.01 grams of PEO. The second combination tested consisted of 0.01 grams of sodium salt and 0.01 mL anionic polyacrylamide. Thirdly, 0.01 mL of anionic polyacrylamide was tested with 0.01grams hydrogen peroxide. Fourthly, 0.01 grams of sodium salt and PEO were mixed. Next, adding a third polymer to the mixture was experimented. The first combination of three performed consisted of 0.01 grams sodium salt, 0.01 grams PEO, and 0.01 mL anionic polyacrylamide. The second combination included 0.02 ml anionic polyacrylamide, 0.02 grams polyacridylnitrile, and 0.02 grams PEO. This combination was performed twice since it flocculated well and for more accurate results.

Results & Discussion

The following section discusses results that were obtained from the previously described testing. Discussion of said results is also included

Turbine Exhaust Case

The results collected from the nickel brush plating hazardous waste storage tank are summarized in Table 3.

Table 3: Nickel Brush Plating Hazardous Waste Sample Results

Metal Tested	Concentration (mg/L)
Lead	3.1
Chromium	21

The levels of lead and chromium classify this waste storage as hazardous waste. The etching step of the nickel brush plating deposits these metals into the waste storage container. This sample was gathered when the 15 gallon waste container was full to about the four gallon mark. Considering the levels of lead and chromium required to classify waste as hazardous, it would be impossible to fill the entire 15 gallon waste storage container below the required chemical limits. Therefore, it would be more efficient to fill the waste storage with the highest concentration of hazardous waste in relation to the water as possible to reduce the amount of times the containers needs to be taken off-site to be emptied. One possible solution to maximize the concentration of hazardous waste in the storage container is to reduce the amount of distilled (DI) water used to rinse the parts in between the use of plating solutions, or to have the DI water enter a separate container. The amount of DI used causes the waste storage to fill up quickly with DI waste. This DI waste could enter a different container because it will contain a negligible amount of lead or chromium, and the hazardous waste storage will be utilized for the more contaminated waste.

Wastewater Treatment

Analysis of On-Site Samples

The results of the ICP testing on the first set of samples from the on-site wastewater system are evidenced in Tables 4-6. These heavy metal concentrations serve as the initial concentrations when used to determine the percentages of metal removed from the samples.

Table 4: Wastewater Treatment Equalization Tank, Sample Set 1 Results

Metal Tested	Concentration (mg/L)
Cadmium	Non-Detectable
Chromium	0.0051
Lead	Non-Detectable
Zinc	0.083
Titanium	0.25
Nickel	0.13
Copper	0.0090
Aluminum	0.068

Table 5: Wastewater Treatment pH Reactor Two, Sample Set 1 Results

Metal Tested	Concentration (mg/L)
Cadmium	Non-Detectable
Chromium	0.37
Lead	Non-Detectable
Zinc	0.29
Titanium	25
Nickel	0.23
Copper	0.053
Aluminum	0.87

Table 6: Wastewater Treatment Clarifier, Sample Set 1 Results

Metal Tested	Concentration (mg/L)
Cadmium	Non-Detectable
Chromium	0.0037
Lead	Non-Detectable
Zinc	Non-Detectable
Titanium	0.064
Nickel	1.4
Copper	0.0038
Aluminum	0.13

It would be expected that, if the wastewater system was operating at its peak of efficiency, the concentrations of the hazardous heavy metals in the water samples would decrease as the water moved through the system from the equalization tank, to the reactor, to the clarifier. However, this is not the trend that is observed going from the equalization tank to the second pH reactor. In fact, except for the cadmium and the lead which remained undetectable, the concentrations of all of the metals tested increased between these two sample locations. A proposed reason for this could be that there is built up metal waste in the pH reactor that is adding additional metal to wastewater at that step. This build-up could be due to an excessive amount of polymer being added to the reactor, supporting the team's test of polymer usage. To test to see if the metal build-up could be contributing to the higher than expected concentrations, the wastewater system was flushed clean and then the team retested samples to see if there was an improvement.

Table 7: Wastewater Treatment pH Reactor Two, Sample Set 2 Results

Metal Tested	Concentration (mg/L)
Cadmium	Non-Detectable
Chromium	0.073
Lead	Non-Detectable
Zinc	0.20
Titanium	4.0
Nickel	0.093
Copper	0.10
Aluminum	0.46

The results obtained from these second tests were in line with what is to be expected. Aside from the nickel concentration, all of the other metal concentrations are at their lowest in the clarifier. This means that, as the wastewater travels through the process, more and more heavy metals are removed, leading to a cleaner effluent as desired. The fact that the nickel concentration did not decrease could mean that the polymer being used is not effective in precipitating out nickel or that the pH of the solution is not in the range ideal for nickel precipitation. Also, cadmium and lead levels were non-detectable, and chromium was low, as well. Therefore, these metals may be neglected in further testing.

An assumption made in this analysis is that the wastewater being sampled is well mixed. In reality, however, this may not be the case; and this fact may lend itself to the questionable test results. It is also not necessarily possible to test the same batch of water as it flows through the process. While the team has to assume that all the water behaves similarly, different batches of water will have different initial concentrations of metals which will alter the sample results.

System Balance

In order to check the validity of the results obtained from the on-site plant, the group conducted a study into the balance of the system. Four key steps in the process from which samples were collected were the equalization tank, the second pH reactor, the clarifier, and the filter cake end product. Assuming 100% success of the system to remove heavy metals from the water, the amount of heavy metal entering the process should equal the amount of heavy metal found in the filter cake. The group chose the first set of data collected from the system to use for this analysis. The results for the amount of metal in each step were reported in mg/L; however, in order to convert the amount of metal into a flow rate, the values were converted into mg/min. These converted amounts per process step are shown in Figure 15.

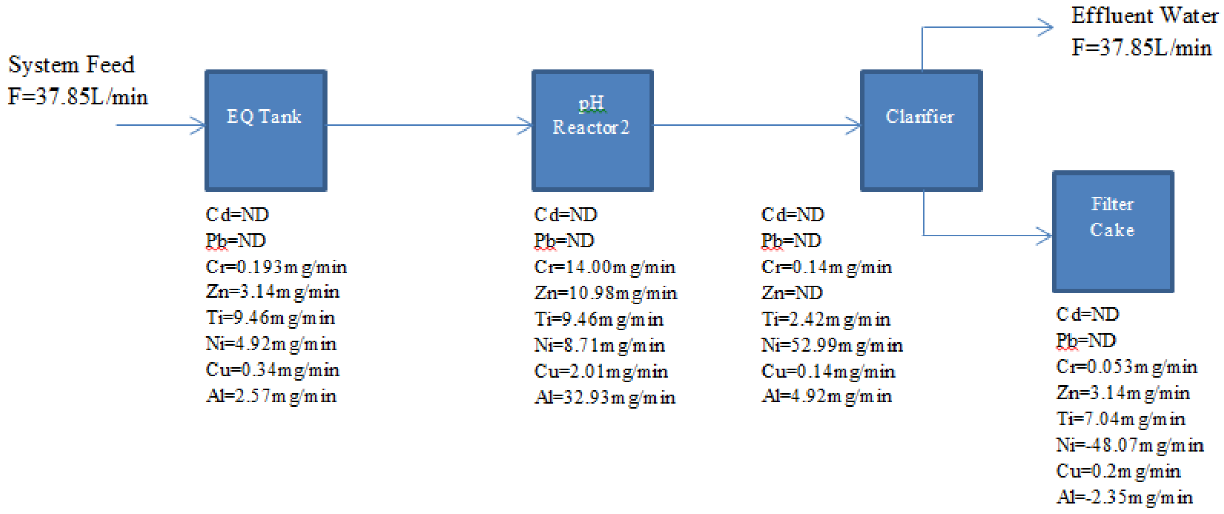

Figure 15: Sample Waste Water System Balance

The system inlet flow rate is calculated assuming the system is being run at its maximum feed rate of 10gpm. It is assumed that the effluent water flow rate is the same as the inlet. A main obstacle to completing the system balance was the lack of test results for filter cake samples. Therefore, it was assumed that the filter cake compositions would be, ideally, those of the equalization tank minus those of the clarifier. The other hurdle that the filter cake poses is that the metal concentrations were calculated as flowing; however, the filter cake is a solid that is building up instead. The problem that is observed with this assumption is that some of the filter cake compositions come out to be negative, pointing to the fact that the systems is not completely in balance. If the process was running efficiently, the concentrations of each metal would decrease with each step in the process. However, as can be seen with the chromium going from the equalization tank to the pH reactor, for example, the amount of the heavy metal increases instead of decreases as is desired. Most of these discrepancies are present in the pH reactor, meaning that this is indeed a good place for the group to start their investigation of system optimization. This also points to the fact that there is indeed a problem of accumulation in the reactors. Therefore, in order to achieve an accurate system balance, the process would need to be flushed and emptied in order to remove accumulation and reinstate flow through the entire volume.

On-Campus Testing

Current Polymer

After the testing of the current GE polymer, anionic polyacrylamide, at different pH's and concentrations, the results were analyzed. Observations were made during the simulations and the resulting solution was sent to the laboratory in order to determine how much metal remained in the solution. Table 8 outlines the results from ICP testing.

Table 8: GE Polymer Jar Testing ICP Results

	pH	Amt. of Chemical (mL)	Chromium	Lead	Zinc	Titanium	Nickel	Copper	Aluminum	Observations
Original	7	0	0.37	ND	0.29	25	0.23	0.053	0.87	NA
S1	7	2	ND	0.0071	0.024	0.012	0.0088	0.047	0.064	Little to no flocc
S2	7	3	ND	0.0039	0.035	0.029	0.011	0.04	0.071	A lot of flocc
S3	7	1	ND	0.0055	0.061	0.0078	0.0086	0.027	0.062	A good amount of flocc instantly
S4	7	0.5	ND	0.006	0.016	0.0091	0.01	0.028	0.058	Moderate flocc
S5	7	0.25	ND	0.0086	0.013	0.005	0.012	0.026	0.06	Flocc when allowed to settle
S6	14	1	ND	0.007	0.012	ND	0.0028	0.039	0.081	Instant flocc
S7	12	1	ND	0.0046	0.01	ND	0.0024	0.029	0.054	Flocc but not large clumps
S8	10	1	ND	0.012	0.006	ND	0.0048	0.032	0.068	Opaque
S9	11	1	ND	0.0073	0.0046	ND	0.004	0.032	0.071	A lot of flocc
S10	11	0.5	ND	0.0075	0.0036	ND	0.0024	0.031	0.05	Flocc chunks after 2 min of stirring
S11	11	0.5	ND	0.0076	0.015	0.0084	0.0023	0.038	0.054	Viscous film formed
S12	8	5	0.008	0.007	0.049	0.63	0.017	0.049	0.17	Foggy with "fluffy" flocc
S13	7	1	ND	0.0062	0.0075	0.024	0.0098	0.027	0.065	Large flocc clumps
S14	8	0.5	ND	0.0073	0.0098	0.0026	0.009	0.025	0.065	No substantial flocc
S15	9	0.25	ND	0.0053	0.015	0.024	0.0097	0.043	0.1	Very opaque
S16	9	2	ND	0.022	0.016	0.04	0.014	0.051	0.061	Light flocc with a film along glass
S17	9	1	0.0034	0.0051	0.025	0.27	0.015	0.041	0.072	A lot of flocc
S18	9	0.5	ND	0.0086	0.0086	0.03	0.013	0.027	0.059	A good amount of flocc
S19	9	0.25	ND	0.0071	0.0078	0.023	0.016	0.026	0.054	Flocc appears dusty

The samples tested were all listed in the order that they were collected. The result "ND" signifies an amount of the metal that was not detectable. The red numbers signify the highest amount of metal detected in all of the trials for that metal. As noted, this trial was different for each metal and allowed the team to eliminate that trial from the optimization. The values highlighted green symbolize the least amount of metal left in the solution after testing. Trial S10 was determined to be the most optimized scenario because it had the minimized amount of metal left in the water after treatment.

Trial S10 was conducted on a smaller scale using the recommended GE proportions. The measured and standard amount of calcium chloride per GE's recommendations was used, as well as 0.01 mL of sodium hydroxide to adjust the pH to 11. A 0.5mL of polymer was added to the solution in order to assist flocculation. During the experiment, it was observed that flocculation occurred within 30 seconds of the addition to the solution and debris settled to the bottom when stirring was halted at the end of the experiment. The team observed the most flocculation during this trail, corresponding directly to the low amounts of metals remaining in the solution after flocculation.

Figure 16 outlines a plot to display the two main hazardous metals desired for removal, chromium and titanium. It compares the hazardous metals removed per each run performed. Labeled on the horizontal axis, 1 is chromium, and 2 is titanium. This figure also outlines the first trial with anionic polyacrylamide while Figure 17 displays the second trial with polyacrylamide.

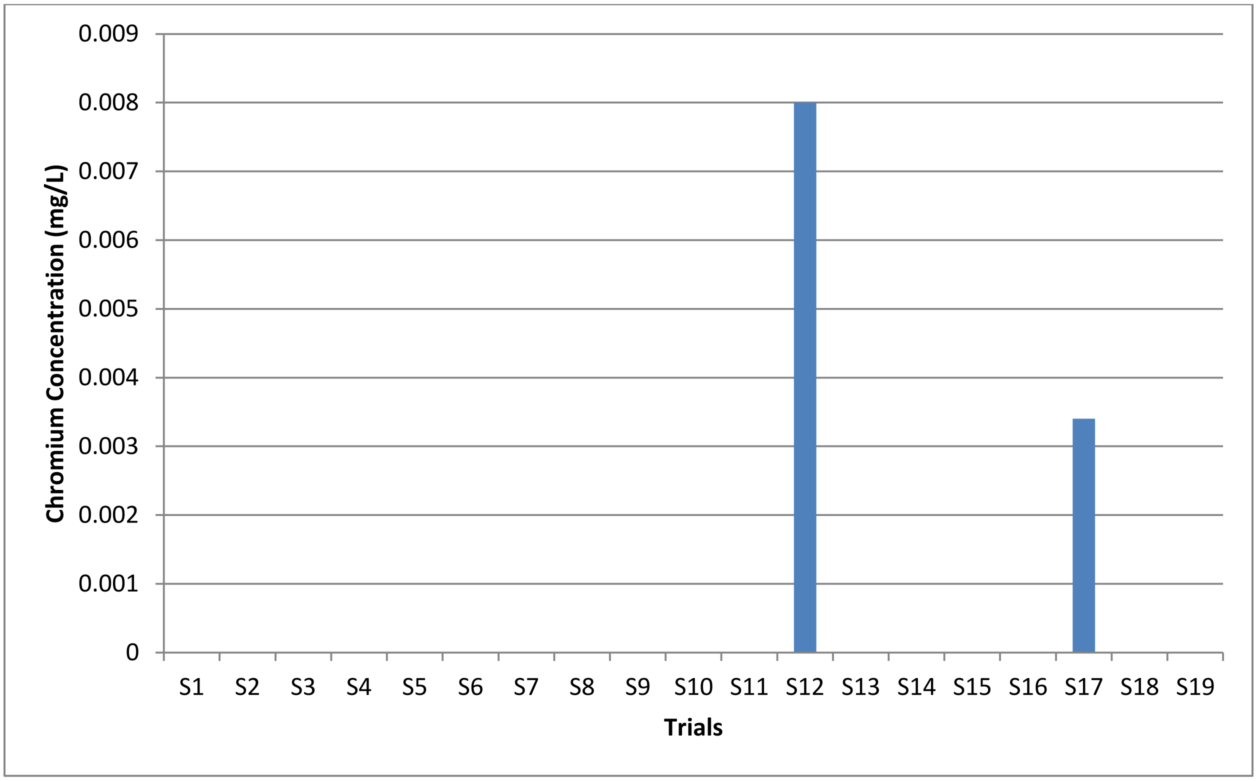

Figure 16: GE Polymer Trial #1 Chromium Results

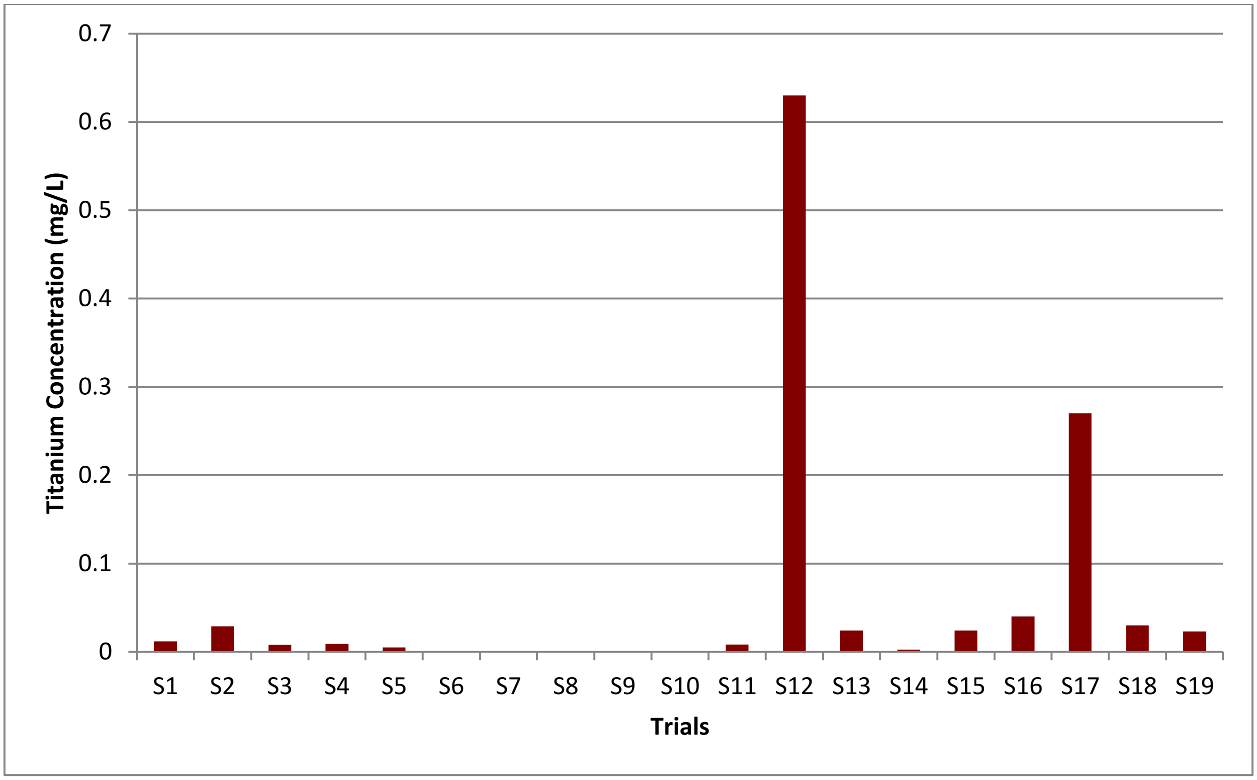

Figure 17: GE Polymer Trial #1 Titanium Results

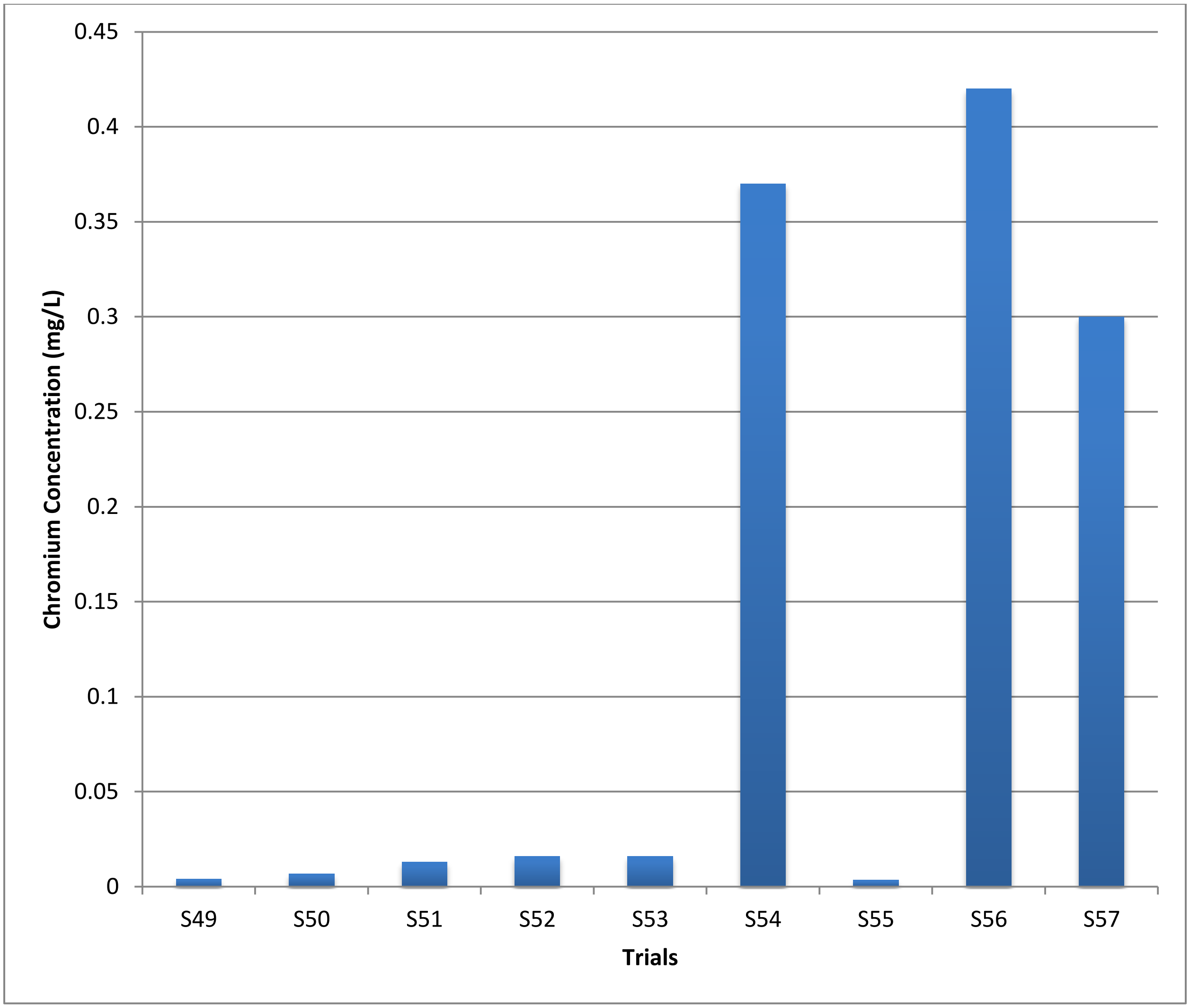

Figure 18: GE Polymer Trial #2 Chromium Results

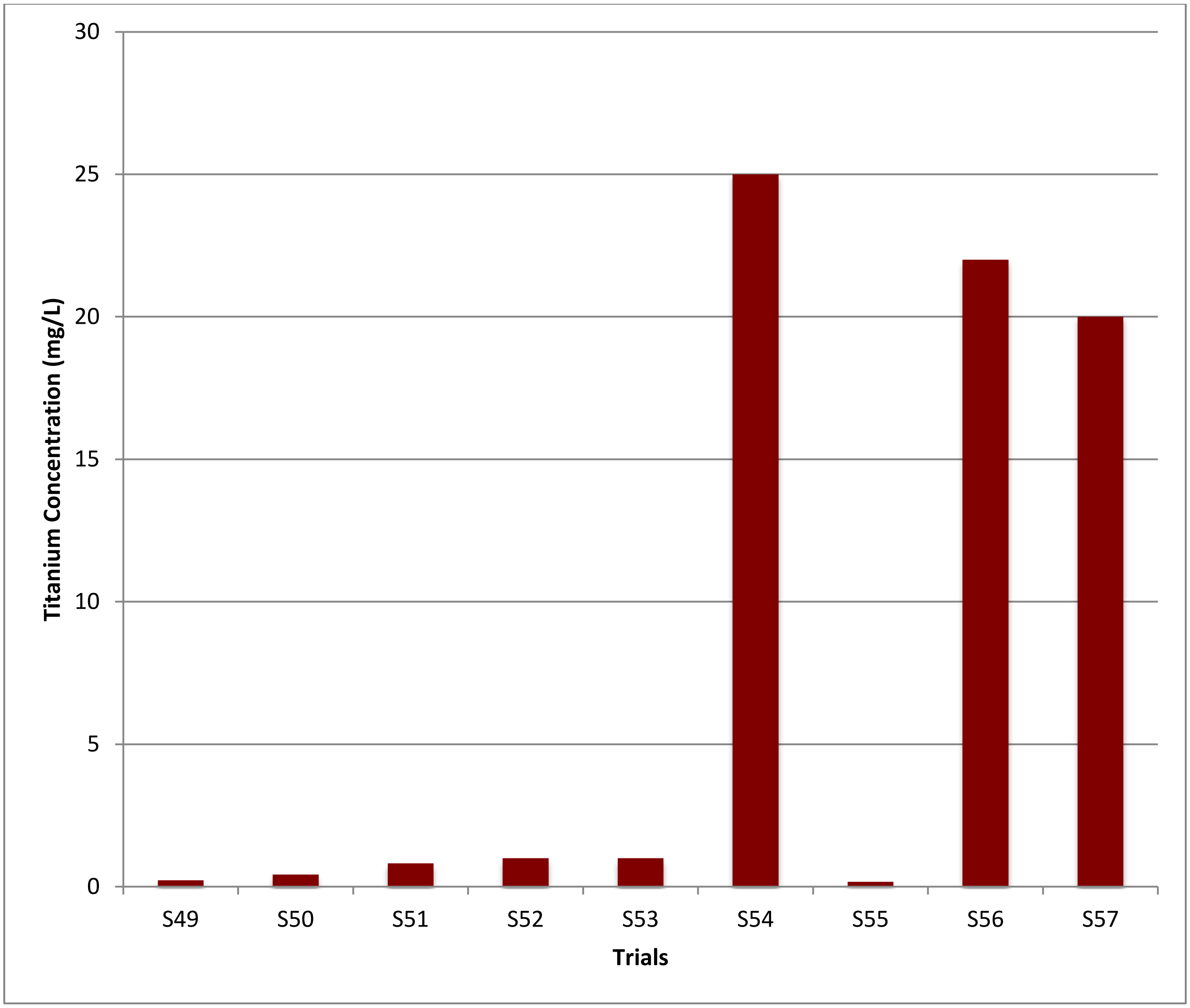

Figure 19: GE Polymer Trial #2 Titanium Results

Hydrogen Peroxide

The next solution tested was the hydrogen peroxide. Table 9 highlights the results from the lab samples for all of the runs using different proportions in the experiment.

Table 9: Hydrogen Peroxide Jar Testing ICP Results

	pH	Amt. of Chemical (mL)	Chromium	Lead	Zinc	Titanium	Nickel	Copper	Aluminum
Original	7	0	ND	ND	0.29	25	0.23	0.053	0.87
S29	7	1	0.0057	0.0047	0.024	0.38	0.018	0.03	0.086
S30	7	3	0.008	0.0078	0.032	0.49	0.016	0.031	0.085
S31	7	1.5	0.017	0.0078	0.086	1.2	0.024	0.034	0.16
S32	7	0.5	0.0098	0.0071	0.019	0.55	0.014	0.027	0.08
S33	8	1	0.0024	0.0043	0.0079	0.051	0.013	0.028	0.06
S34	9	0.5	0.0022	0.0072	0.0037	0.064	0.011	0.027	0.074
S35	9	1	0.0028	0.0051	0.0055	0.066	0.01	0.03	ND
S36	9	1.5	0.029	0.0057	0.0075	0.081	0.011	0.031	ND
S37	9	3	0.0057	0.0036	0.0047	0.12	0.011	0.033	ND
S38	11	1	0.011	0.0049	0.017	0.48	0.01	0.029	0.061

As highlighted, trial S34 was the most successful in extracting heavy metals. In comparison with the polymer currently used by GE, the hydrogen peroxide did very well. The two solutions were comparable because they both extracted metals, but each was more successful with different metals. For example, the hydrogen peroxide was more successful in extracting the chromium, lead, and nickel, while the anionic polyacrylamide extracted the zinc, titanium, copper, and aluminum more effectively. In this case, it is important to study which metals are more hazardous and therefore, more important to extract in this process. On the other hand, trial S31 was not effective at all in extracting metals. The sample the group collected and sent to the GE for testing showed that there was still almost all of the heavy metal from the initial solution. Therefore, it can be concluded that the effectiveness of hydrogen peroxide as a coagulant is very sensitive and dependent upon the exact amount and pH used, with 0.5 mL of hydrogen peroxide and a neutral pH being ideal.

Figure 18 below displays the effects hydrogen peroxide had on chromium and titanium. Chromium is 1 on the horizontal axis and titanium is 2 on the horizontal axis.

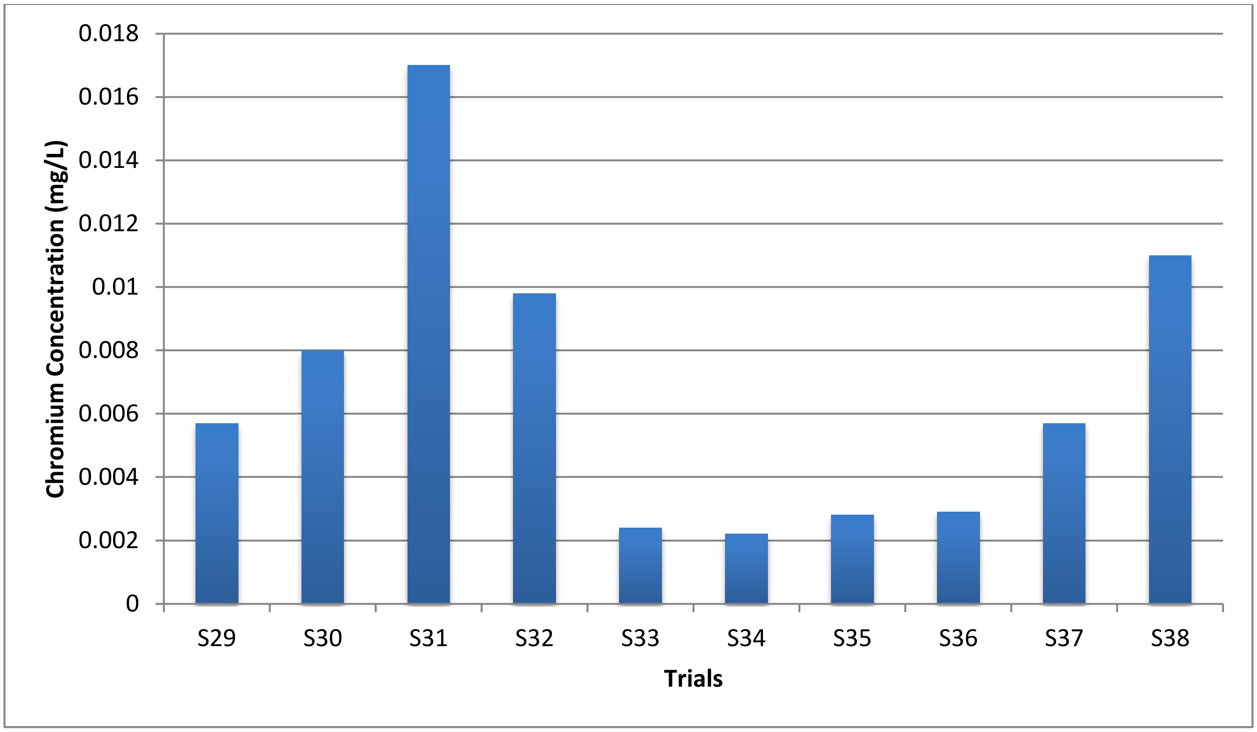

Figure 20: Hydrogen Peroxide Polymer Testing Chromium Results

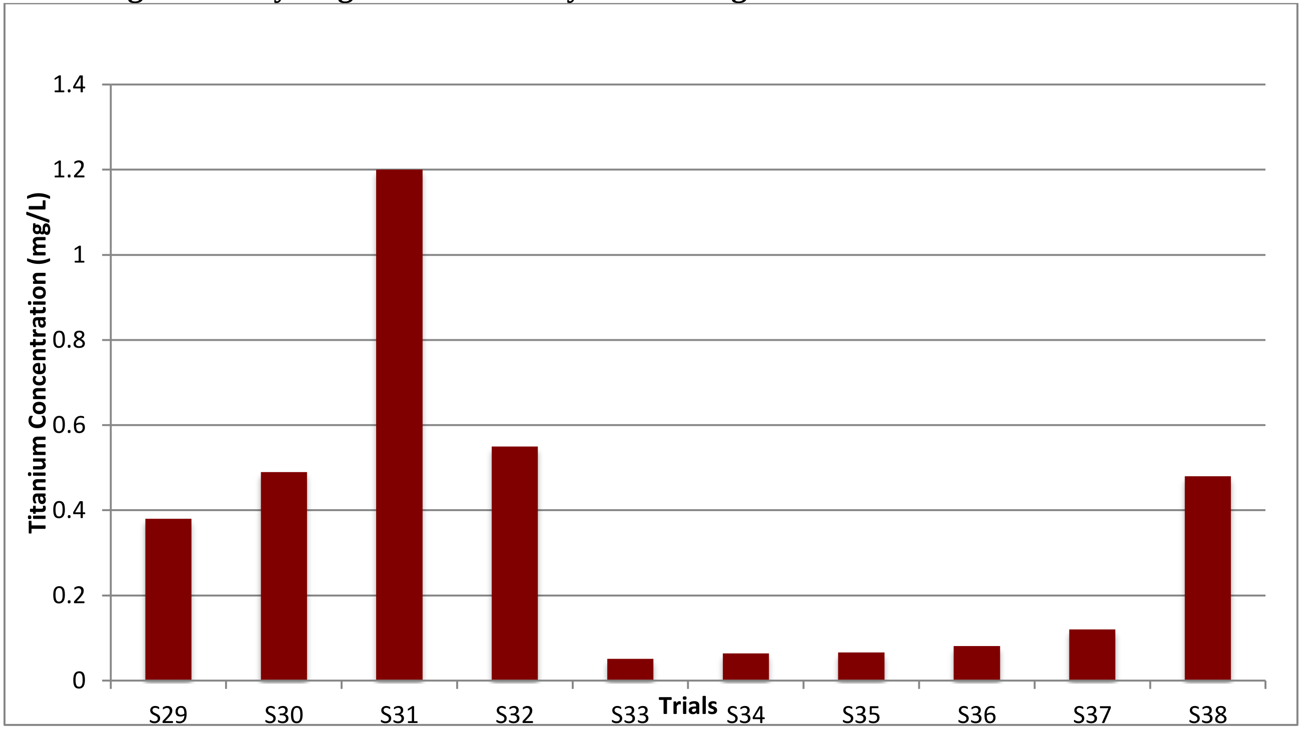

Figure 21: Hydrogen Peroxide Polymer Testing Titanium Results

Poly(ethylene) Glycol

Poly(ethylene) glycol (PEG) was also tested for effectiveness with the wastewater the group collected from GE. The results for the trials run with different proportions of PEG are shown in Table 10.

Table 10: Poly(ethylene) Glycol Jar Testing ICP Results

	pH	Amt. of Chemical (mL)	Chromium	Lead	Zinc	Titanium	Nickel	Copper	Aluminum	Observations
Original	7	0	ND	ND	0.29	25	0.23	0.053	0.87	NA
S20	9	1	ND	0.0049	0.0053	0.0056	0.0076	0.047	ND	“Dusty” flocc
S21	9	0.5	ND	0.007	0.013	ND	0.0082	0.04	ND	“Dusty” flocc
S22	9	0.25	ND	0.0046	0.0073	ND	0.0061	0.027	0.052	“Dusty” flocc
S23	9	2	ND	0.0032	0.0032	ND	0.0053	0.028	0.092	“Dusty” flocc
S24	8	1	0.0022	ND	0.051	0.16	0.014	0.026	0.34	“Dusty” flocc
S25	8	0.5	0.0026	0.0082	0.039	0.16	0.014	0.039	0.21	“Dusty” flocc
S26	8	0.25	0.0022	0.0036	0.023	0.11	0.013	0.029	0.099	“Dusty” flocc
S27	8	2	0.0026	0.0044	0.022	0.16	0.014	0.032	0.15	“Dusty” flocc

Test S23 ended up being the most desirable conditions for using PEG. It extracted the most cadmium, chromium, lead, zinc, and nickel. Both runs S24 and S25 seemed to be the least effective runs for PEG due to the fact that little to no heavy metal extraction was achieved.

Figure 19 below displays the effects PEG had on chromium and titanium. Titanium concentration is 1 on the vertical axis and run number is on the horizontal axis.

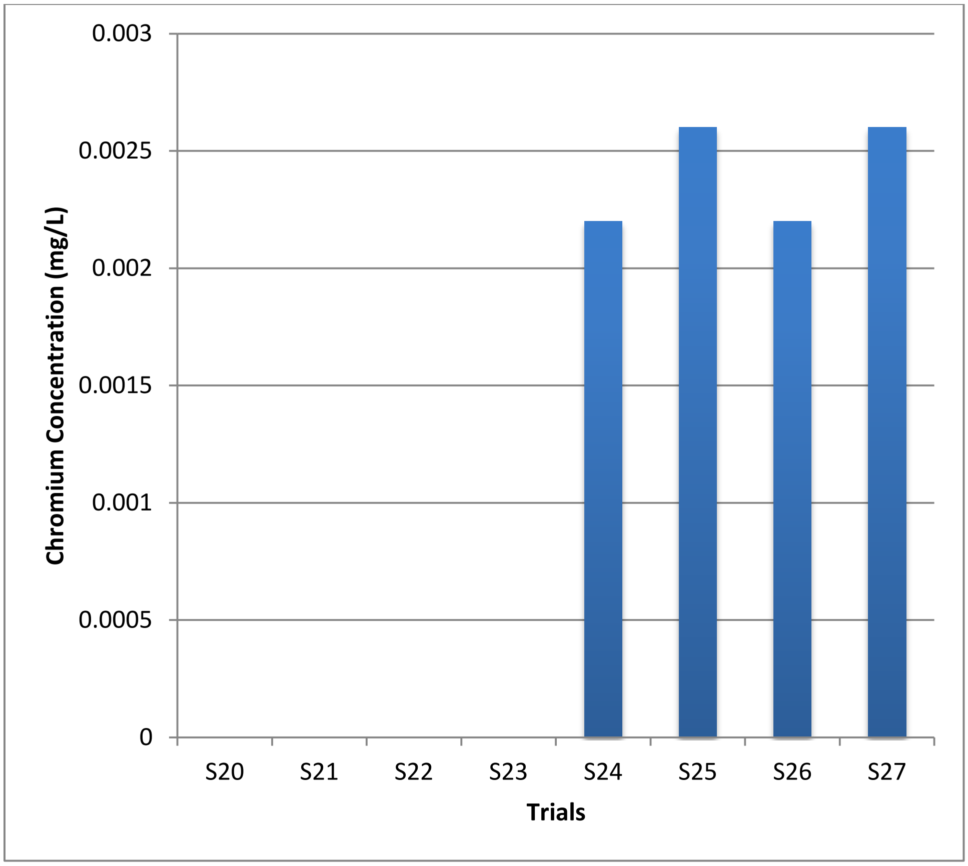

Figure 22: PEG Polymer Testing Chromium Results

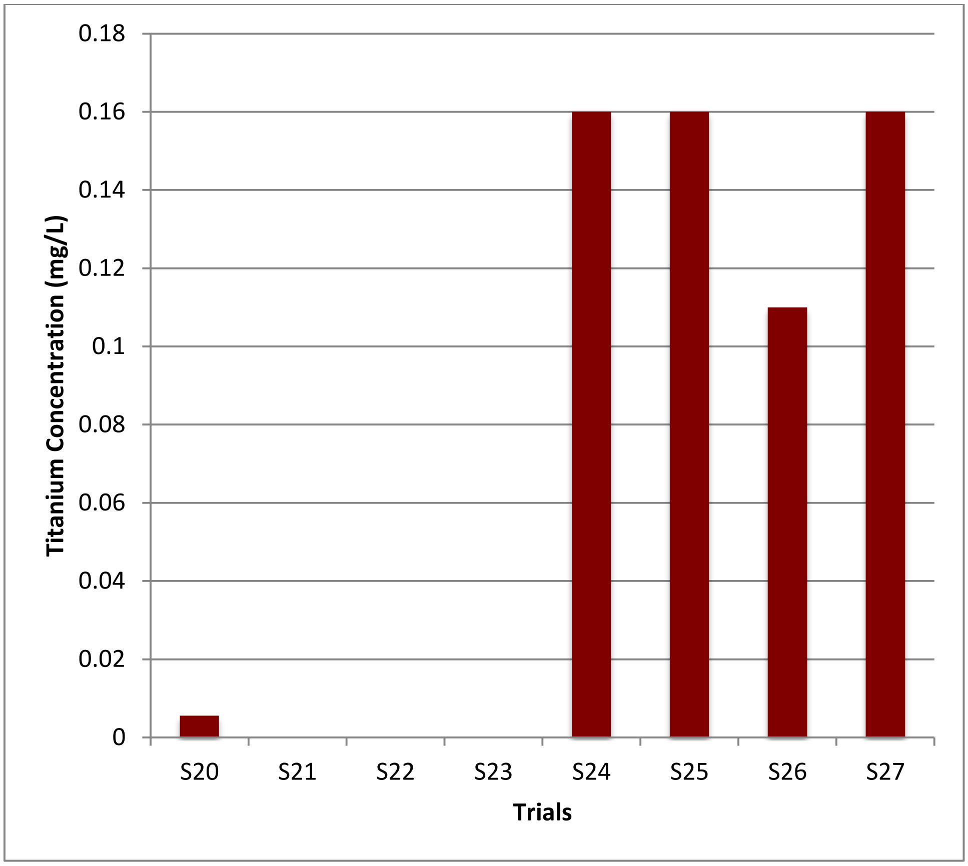

Figure 23: PEG Polymer Testing Titanium Results

Mixed Polymers

Table 11 represents the data from the mixed polymer runs.

Table11: Mixed Polymer Jar Testing ICP Results

	pH	Amt. of Chemical (g)	Chromium	Lead	Zinc	Titanium	Nickel	Copper	Aluminum
Original	7	0	ND	ND	0.29	25	0.23	0.053	0.87
S44	11	0.01	0.019	0.0092	0.052	1.1	0.022	0.033	0.13
S48	7	0.01	0.045	0.0043	0.092	2.7	0.034	0.046	0.24
S46	7	0.01	0.019	0.0061	0.049	1.1	0.021	0.033	0.13
S41	7	0.006	0.053	0.018	0.12	3.3	0.036	0.047	0.3
S42	11	0.01	0.017	0.012	0.045	1	0.021	0.033	0.13
S43	11	0.01	0.018	0.0064	0.051	1	0.021	0.034	0.13
S45	7	0.01	0.018	0.0054	0.048	1	0.021	0.03	0.12
S47	7	0.02	0.054	0.0057	0.11	3.3	0.036	0.045	0.26

Optimal Runs

Each of the chemical and polymer experimentations performed best under a certain set of conditions including amount of polymer/chemical and pH. The results suggest that the polymer used by GE, polyacrylamide, produced the best set of flocculation results compared to the experimental testing of PEG, or hydrogen peroxide. The optimization of a run can be arranged by different parameters.

Polyacrylamide and its' variations are the commonly used polymer products for flocculation and coagulation purposes in many wastewater treatment facilities. Moreover, interviews from third party polymer provider vendors, suggested that many companies treat with a mixture of polymers or ionic variation of PAM.

pH Limitations

The current pH tanks at GE process plant limit the pH levels between 8 and 9. The best flocculation run was found to be at a pH of 11. As a future process change recommendation, the group suggested that the ability to increase the pH be implemented in the event of redesigning of the plant and treatment of the discharge.

Testing Error

There were a number of constraints and sources for error during the teams jar testing in the lab. They can be summarized as follows.

Stirring Time – The engineering team assessed the same stirring time as the one used by the GE process. Variation in stirring time for different polymers and chemicals may have resulted in slightly different results. However, more stirring time may lead to the process being costlier. The recommendation the group provided is aimed at being cost-effective.

Temperature Constraints – Many literature reviews suggest that the polymers and chemicals examined might work better with a combination of perfect stirring time and heating the wastewater feed. However, the group deemed this as cost-ineffective since there are a lot of costs associated with heating the wastewater feed including redesigning of the plant and new equipment.

Possible sources of error in the testing phase include a flake of settled sludge from the sample being caught in the sample concentration tester. The varied results in the concentrations can be attributed to this reason. Though the team managed to filter samples before being sent to the lab for testing, it might have required a more careful filter press and monitoring for more accurate results.

The results from premiere laboratory are very accurate. The samples were repeated for accuracy and confirmed to have the same value for both tests performed. All tests confirmed exactly the same results.

Percent Extractions

The following table summarizes the percent extraction of the metals titanium and chromium for each sample treated with the GE polymer. The sample was given a settling time of four days to analyze the effects of settling time in optimal treatment.

Table 12: Percent Extractions of Chromium and Titanium using GE Polymer

Sample	Chromium %Extracted	Titanium %Extracted
S1	100	99.95
S2	100	99.88
S3	100	99.96
S4	100	99.96
S5	100	99.98
S6	100	100
S7	100	100
S8	100	100
S9	100	100
S10	100	100
S11	100	99.96
S12	97.83	97.48
S13	100	99.904
S14	100	99.98
S15	100	99.90
S16	100	99.84
S17	99.08	98.92
S18	100	99.88
S19	100	99.90

As the data suggests, the GE polymer in total performed more than satisfactorily in the flocculation of metals of concern. On average chromium was extracted at 99.83 % while 99.76 % of titanium was extracted from samples treated with polyacrylamide.

Similarly the following Table summarizes the percent extraction for PEG, hydrogen peroxide.

Table 13: Percent Extraction of Chromium and Titanium using PEG and Hydrogen Peroxide

Poly Ethylene Glycol (PEG)	Chromium %Extrated	Titanium %Extracted
S20	100	99.97
S21	100	100
S22	100	100
S23	100	100
S24	99.40	99.36
S25	99.29	99.36
S26	99.40	99.56
S27	99.29	99.36
Hydrogen Peroxide		
S29	98.45	98.48
S30	97.83	98.04
S31	95.40	95.2
S32	97.35	97.8
S33	99.35	99.79
S34	99.40	99.74
S35	99.24	99.73
S36	99.21	99.67
S37	98.45	99.52
S38	97.02	98.08
S39	95.67	99.76
S40	93.78	94.4

On average, the chromium extracted by PEG is 99.67 % whereas hydrogen peroxide was able to remove about 97.60 % of the chromium. PEG performed slightly better at removing titanium on average than hydrogen peroxide, as they were able to extract 99.70 % and 98.35 % respectively.

As per the suggestions provided by many polymer vendors, the engineering team also carried out a number of jar testing experiments with a mixture of polymers. Their data for percent extraction is summarized in the table below.

Table 14. Chromium and Titanium Percent Extraction using a Mixture of Polymers

Sample	Chromium %Extraction	Titanium %Extraction
S41	85.67	86.8
S42	95.40	96
S43	95.13	96
S44	94.86	95.6
S45	95.13	96
S46	94.86	95.6
S47	98.89	99.12
S48	87.83	89.2

Though the mixture of polymers performed less effectively than GE Polymer, PEG and hydrogen peroxide exclusively, some of the samples performed as well as some of the individual runs carried out using the aforementioned polymers. The poor performance can be attributed to other parameters such as temperature control, stirring, settling time and pH balance.

The average extraction percentage for each of the polymers and chemical is summarized in the Figure 20.

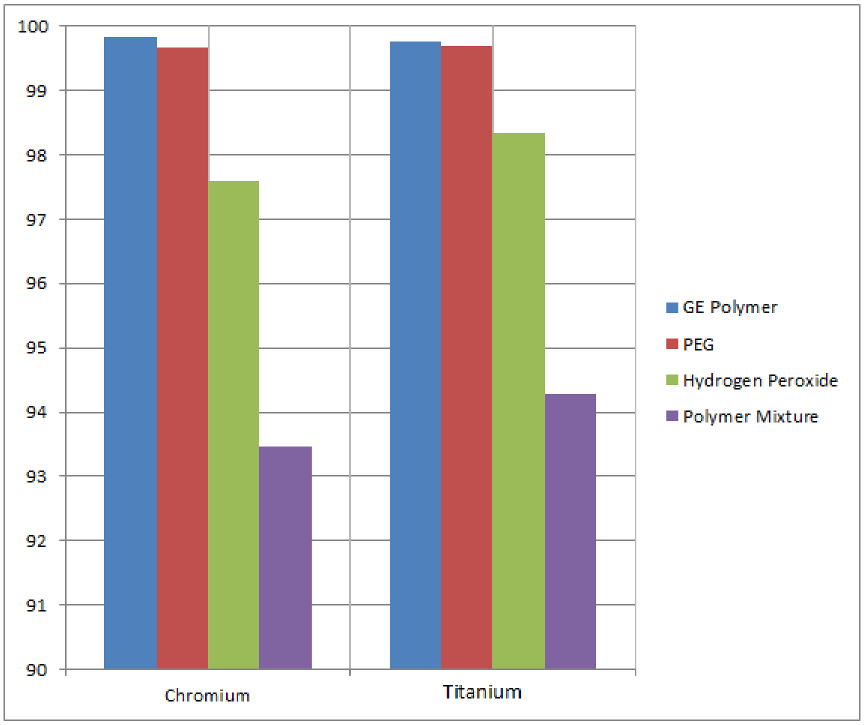

Figure 20. Chromium and Titanium Average Percent Extractions

As a final analysis the engineering team repeated a select few runs from the GE polymer to observe the effect of settling time on flocculation. The percent extractions for the data are summarized in the table below.

Table 15. Percent Extractions of Chromium and Titanium using GE Polymer (Repeated Runs)

Sample	Chromium %Extraction	Titanium % Extraction
S49	98.89	99.12
S50	98.16	98.32
S51	96.48	96.72
S52	95.67	96
S53	95.67	96
S54	0	0
S55	99.08	99.32
S56	13.51	12
S57	18.91	20

On average, 68.48 % of chromium and 68.60 % of titanium was extracted in the repeated runs using GE Polymer. This drastic difference can be attributed to the settling time of about one day compared to the four days of settling time used for the first testing phase of GE Polymer.

Recommendations

After completing testing and obtaining results, the group was able to provide General Electric with the following recommendations to improve their processes.

Turbine Exhaust Case

Separating the Nickel-Containing Wastewater from Other Wastewater

During the brush nickel-plating process, several solutions are applied to the part being plated. These solutions are then rinsed from the part with distilled water while it is spinning in an apparatus. All of the rinse water from these steps is collected in a single hazardous wastewater tank. The wastewater is considered hazardous due to the high lead and chromium concentrations within it. However, the amount of wastewater generated from this process is excessive because not all of the solutions that are being rinsed from the part contain a significant amount of these heavy metals. Therefore, it is proposed to have separate drains for different steps in the rinsing process. The cleaning, stripping, and de-smutting solutions do not contain any heavy metal; therefore, the wastewater generated from the rinsing of these solutions from the parts contains only trace metals washed from the part. However, when the actual nickel-plating solution is applied to the part, there is a great deal of excess metal that is rinsed away. If there are two drains in the bottom of the rinsing/spinning apparatus, then opening one at a time for each specific process rinsing step would allow the rinse water with and then without the heavy metals to go into separate wastewater tanks. This would allow for the lead/chromium-containing hazardous waste and the non-lead/chromium containing wastewater to be treated in the way that is most efficient and convenient to the company, while decreasing the total volume of hazardous waste. While separating the streams is an option, it may not be the most effective process due to the heavy volume of waste on the final step of the process.

Figure 24: Current Rinsing Set-Up

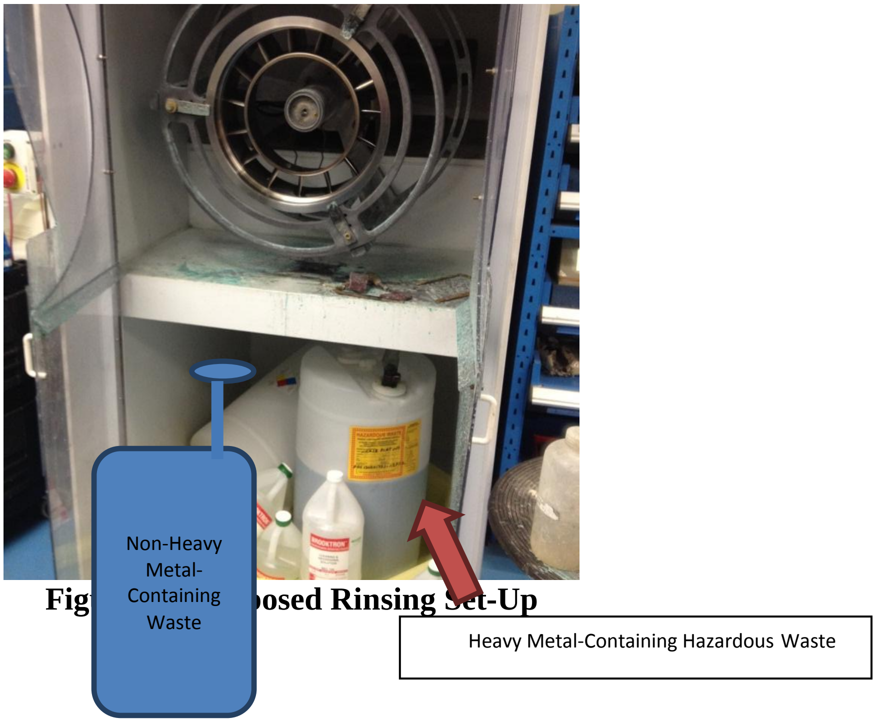

Fig osed Rinsing Set-Up

New Equipment for Nickel Plating

Brooktronics Inc. is currently the provider of the machinery and acid wash solutions for the nickel-plating process for GE. The model from Brooktronics is more than a decade old and is poorly maintained. In order to make the process more organized and efficient, research was conducted on possible replacement for the equipment.

Liquid Development Company offers a range of machines for brush plating purposes. Since 1978, when they were first established, they have claimed to have made many advances in equipment and technology for brush nickel plating. They offer a “portable power pack” that is efficient, convenient and clean for brush plating. The company also claims to have great precision and control of the equipment and system and guarantees a faster process. Given the fact that the nickel brush plating process is fairly small scale, this company and their equipment may be beneficial.

Sifco Applied Surface Concepts is another company that offers a wide variety of equipment and solutions for plating purposes. Unlike Liquid Development Company who specializes in nickel plating, Sifco offers a wide range of machinery for different industries. The company does provide a wide range of equipment for nickel brush plating that is comparatively newer than the equipment currently in use at GE-Aviation. However, Sifco’s constraint is that the solutions that are sold via the company website must be tested to check for efficiency.

After speaking with engineers and contractors at Liquid Development Company and Sifco Applied Surface Concepts, they asked that the parts manufactured by GE be provided and investigated so that they may recommend the best equipment. Provided that some engine part information is proprietary, a full investigation could not be carried out. The contractors also could not provide specific information regarding the pricing on the machinery and solutions. However, they claim that the equipment is within the price range of the machines purchased from Brooktronics.

As a recommendation, it is advised that for a more efficient process, equipment from Liquid Development Company or Sifco Applied Surface Concepts be tested and considered for installation at GE-Aviation.

Wastewater Treatment

Strictly Data Driven Recommendations

Per the guidance of the group's on-site advisors, the heavy metals of particular interest to GE are titanium and chromium, as these are the metals that have been the most difficult to remove in the past. Additionally, titanium has been present in large concentrations due to the fact that the wastewater is generated from the washing of parts that are titanium etched. Compared at a pH of 9 and 1mL of chemical used, the concentrations of heavy metal remaining in the wastewater after flocculation are compared.

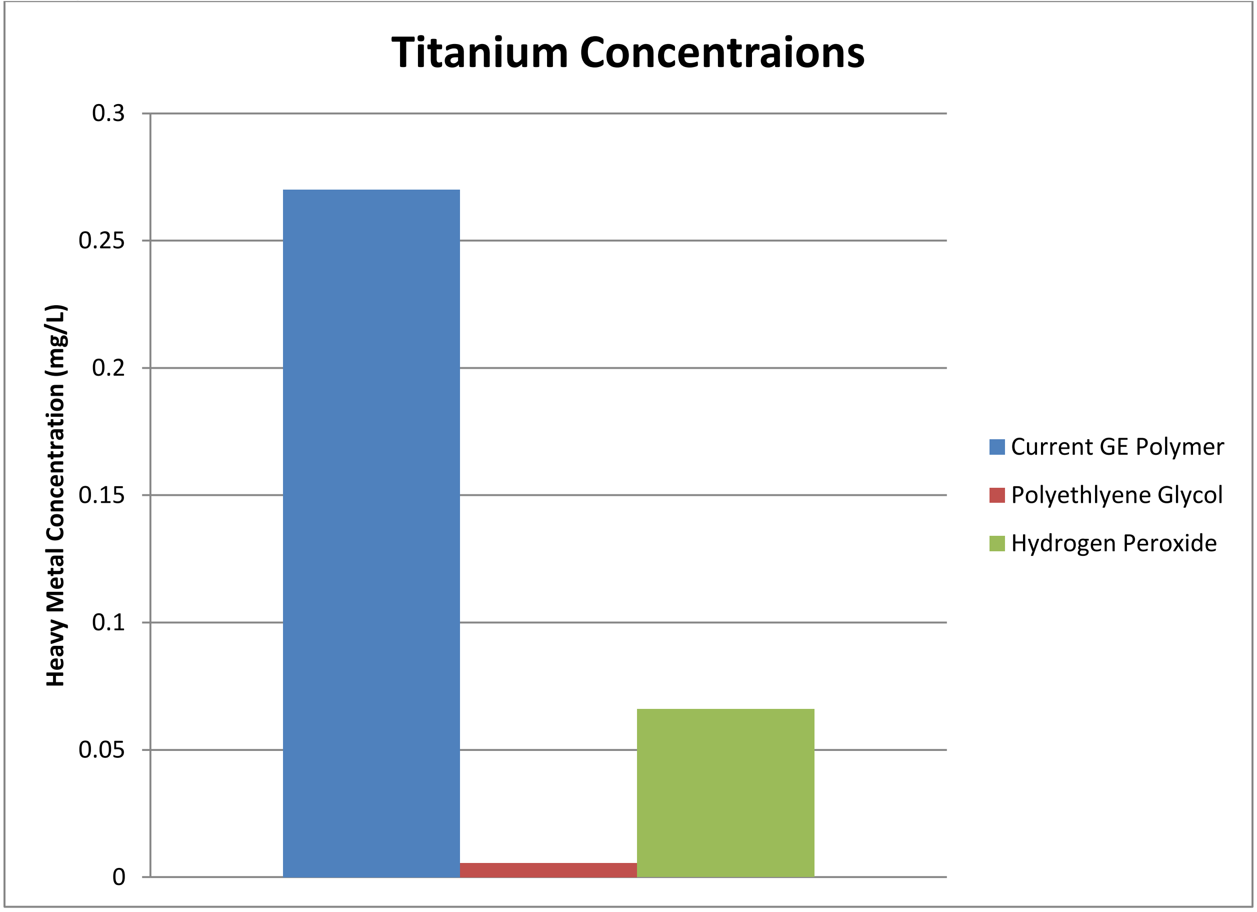

Figure 22: Final Titanium Concentrations Comparison

Based on the data at these conditions alone, the chemical that was the most effective at removing the titanium from the wastewater was polyethylene glycol.

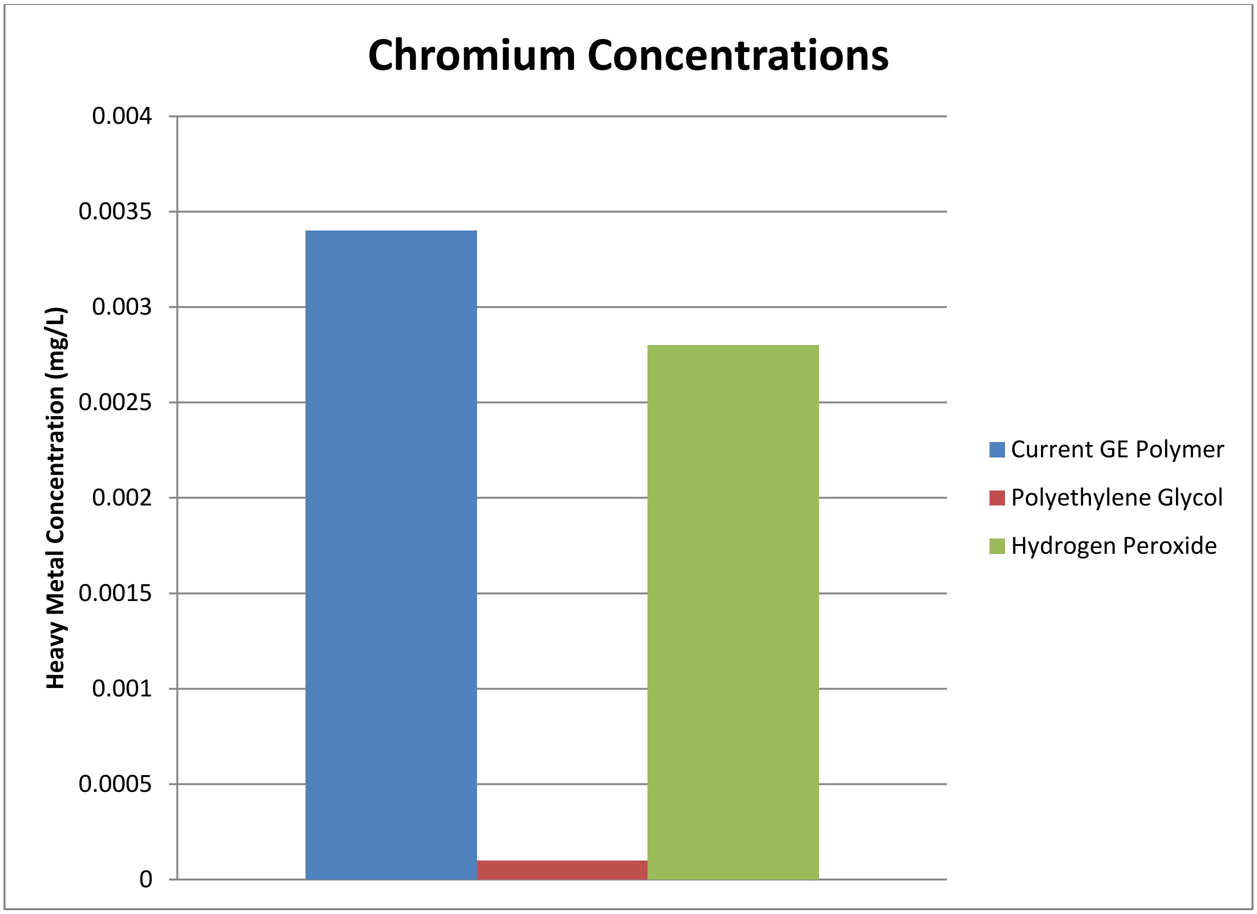

Figure 23: Final Chromium Concentrations Comparison

Based on the data at these conditions alone, the chemical that was the most effective at removing the chromium from the wastewater was polyethylene glycol, as well. However, these cannot be considered final recommendations because economic considerations, as well as the limitations of the facility must be taking into account.

Economic Considerations

In reviewing the data to make recommendations to GE Aviation, it is important to also evaluate the economic factors that the plant will experience. Though some of our trials extracted more metal, they may not be the best overall recommendation for GE. The team was able to contact Chic Dunklee at Gilbert and Jones to better estimate pricing for all of the chemicals used in the experiments. With those numbers, the team was able to conduct a cost analysis on the proportions of chemicals used to their cost, giving GE a final cost estimate for improvements. Appendix D provides the full chart and analysis conducted.

The chemical pricing was provided to the team in cost per pound of polymer. The team was able to convert the cost per pound to cost per milliliter by utilizing the density of each chemical on their individual MSDS's. The Calcium Chloride added in each run was also accounted for. For each trial run and sample collected, the team was able to obtain the cost per milliliter of chemical used. When the total cost per milliliter was obtained, the team scaled the price up to represent the cost associated with each gallon of wastewater treated. With these numbers, General Electric will be able to better anticipate how much they will spend each year depending on the average number of gallons they treat.

Overall, the best economic value for materials used was experienced in S43. This trial minimized the amount caustic and polymer to produce effective results within permit limits. This trial still may not be the most effective for GE to use because the overall system operated at a pH of 11. It is possible that in the future, with new machines, this trial will be best fit for the plant.

Beyond that, the current GE polymer, anionic polyacrylamide, and polyethylene glycol extract large amounts of metals in the process. Trials S15, S19, S22, S26, and S55 were the next most effective. The proportions of these metals can be found in the results and discussion section and the full results for the full cost analysis can be found in Appendix D. Below is a table highlighting the amount of polymer used in each trial for the least expensive runs. All trials below operate at a pH in the range from 8-10.

Table 11: Cost Evaluation for Least Expensive Trials

	Caustic Conc (M)	mL Caustic	Cost per mL	Cost Caustic $	Anionic Polyacrylamide	Cost per mL	Cost AP $	Cost per mL	Cost per Gallon
S15	0.1	0.01	0.0016	0.00013	0.25	0.013	0.0033	0.0034	$0.06
S19	0.1	0.02	0.0016	0.00013	0.25	0.013	0.0033	0.0034	$0.06
S22	0.1	0.03	0.0016	0.00013	0.25	0.013	0.0033	0.0034	$0.06
S26	0.1	0.02	0.0016	0.00013	0.25	0.013	0.0033	0.0034	$0.06
S55	0.1	0.02	0.0016	0.00013	0.25	0.013	0.0033	0.0034	$0.06

Ultimately, the current GE process was evaluated against the proposed changes. In carrying out the same calculations for the GE polymer and proportions, it was determined that $0.24 is spent per gallon of wastewater treated. As seen above, the recommended combinations result in a $0.06 per gallon cost. That being said, GE has the capability to save $0.18 per gallon of wastewater treated- a 75.0% savings. With the plant capabilities, the team believes that this can result in a great cost improvement and more standardized procedure.

Final Recommendations

For the nickel plating process, the engineering team suggests that upon experimentation with the equipment provided by the recommended companies (Liquid Development Company and Sifco Applied Surface Concepts) the plant could determine an adequate installation of more environmentally friendly equipment. Furthermore, rising liquids such as CitruClean might prove to be an effective improvement for the current process.

Many of the polymers tested were able to function at the specified pH's and extracted metal from the solution. In the lab, the team was able to identify the chemicals that extracted the most metal to be sure GE was within their permit limits. After conducting an economic analysis, the team provides the following recommendation to GE Aviation:

- Anionic polyacrylamide polymer that GE currently uses was able to extract the most metal from the solution strictly based on lab results

- Mixed polymers can be more effective in correct proportions, but at a higher pH: the combination of the sodium salt solution and the anionic polyacrylamide allowed for a minimal amount of caustic used and, in result, less polymer
- GE can save up to 74.1% per year if following the provided proportions of chemicals

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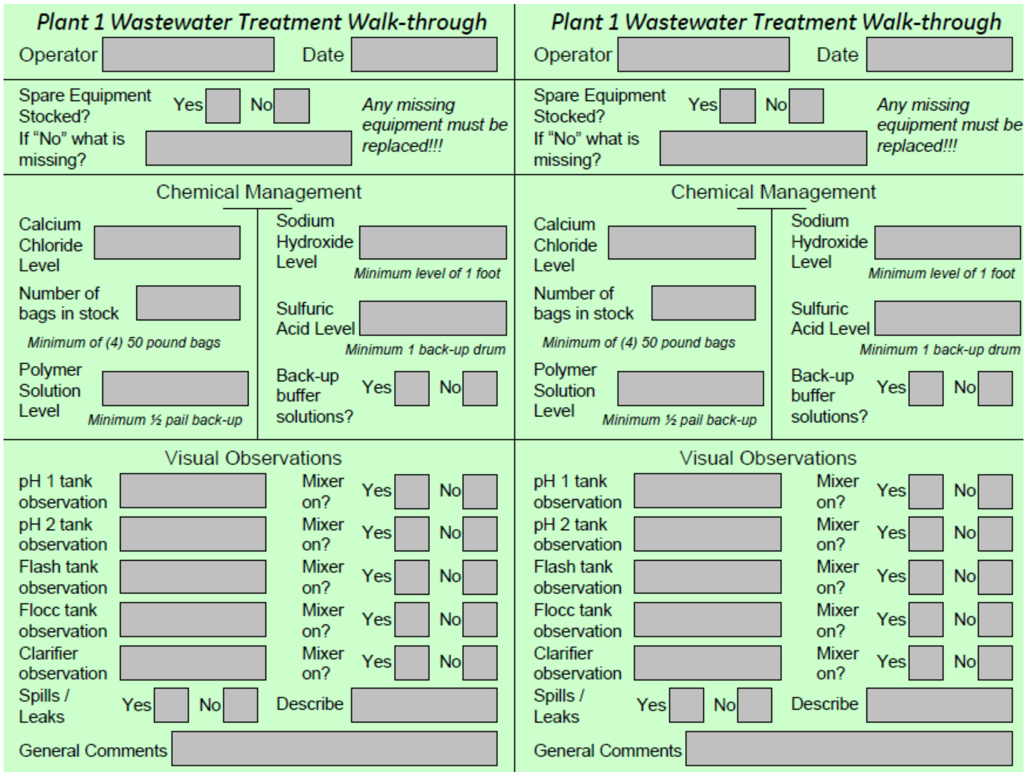
Appendices

Appendix A: Daily Wastewater Treatment Walkthrough Checklist



Plant 1 Wastewater Treatment Walk-through

Operator
Date

Spare Equipment Stocked? Yes ☐ No ☐
If "No" what is missing?
Any missing equipment must be replaced!!!

Chemical Management

Calcium Chloride Level
Number of bags in stock
Minimum of (4) 50 pound bags
Polymer Solution Level
Minimum ½ pail back-up
Sodium Hydroxide Level
Minimum level of 1 foot
Sulfuric Acid Level
Minimum 1 back-up drum
Back-up buffer solutions? Yes ☐ No ☐

Visual Observations

pH 1 tank observation
Mixer on? Yes ☐ No ☐
pH 2 tank observation
Mixer on? Yes ☐ No ☐
Flash tank observation
Mixer on? Yes ☐ No ☐
Flocc tank observation
Mixer on? Yes ☐ No ☐
Clarifier observation
Mixer on? Yes ☐ No ☐
Spills / Leaks Yes ☐ No ☐
Describe
General Comments

Plant 1 Wastewater Treatment Walk-through

Operator
Date

Spare Equipment Stocked? Yes ☐ No ☐
If "No" what is missing?
Any missing equipment must be replaced!!!

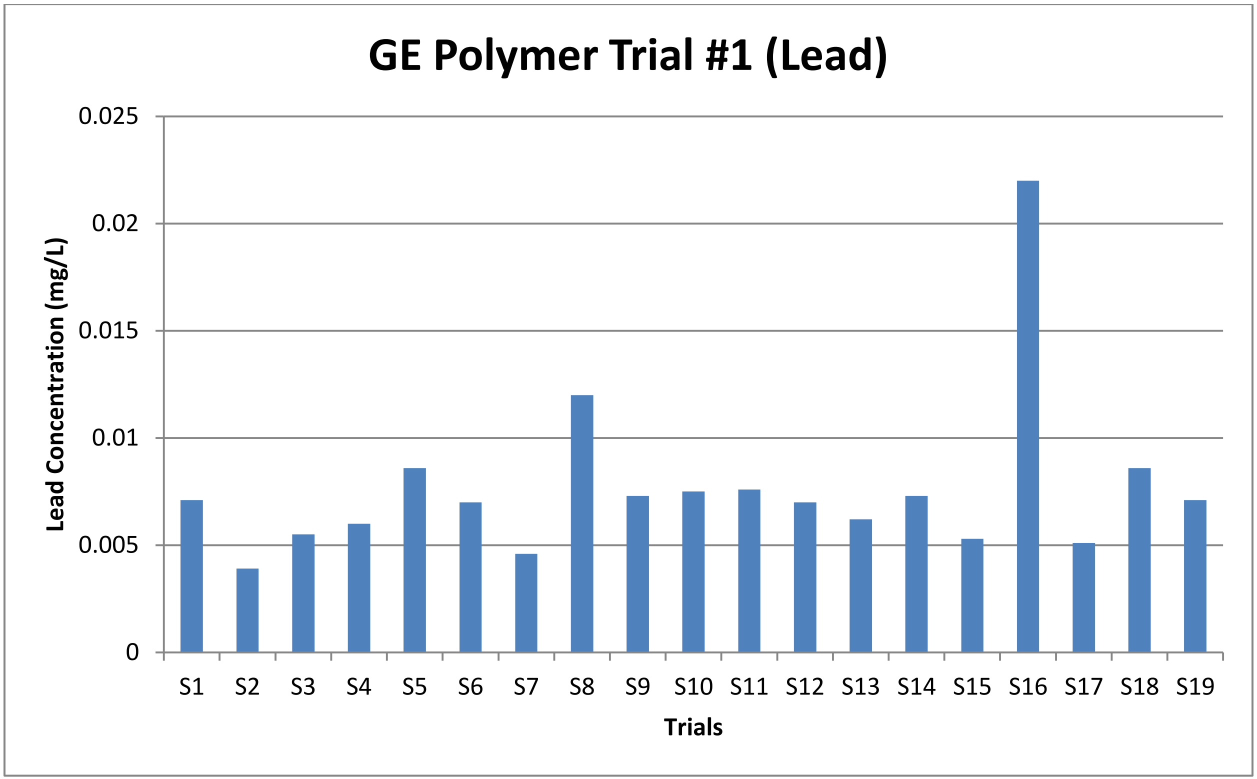
Chemical Management

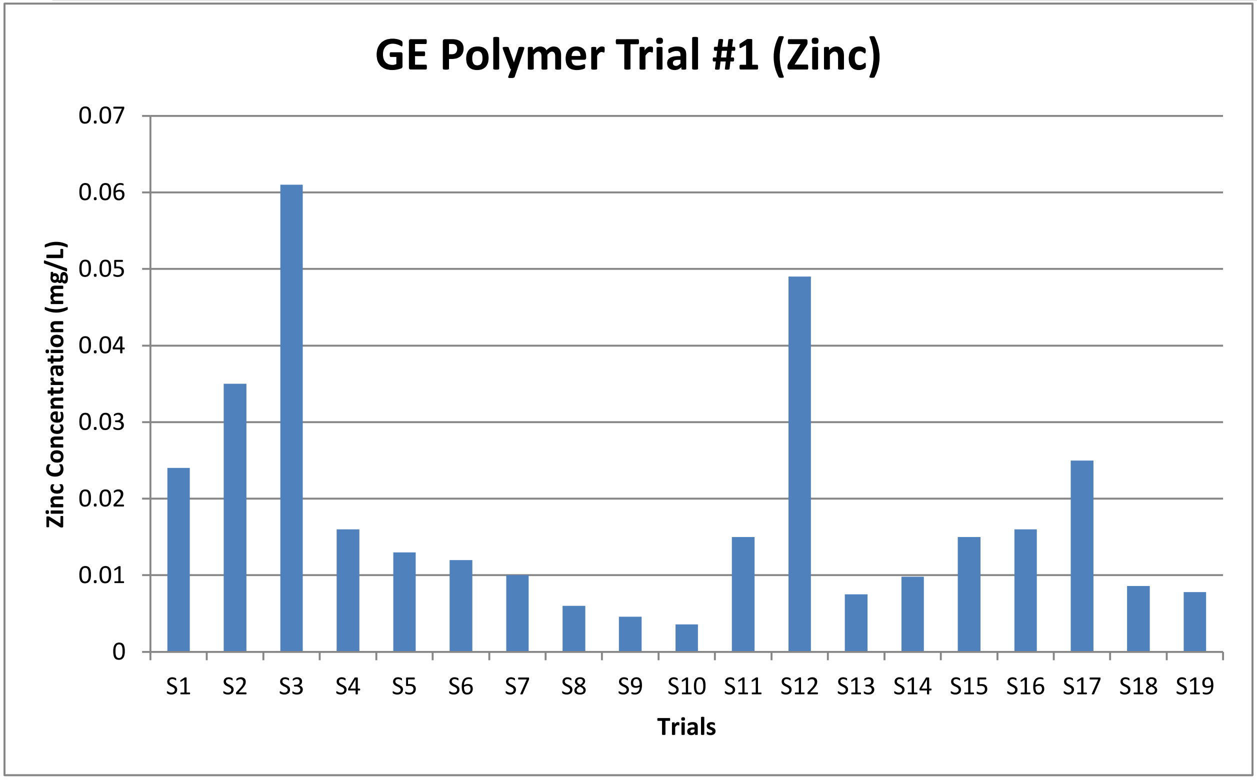
Calcium Chloride Level
Number of bags in stock
Minimum of (4) 50 pound bags
Polymer Solution Level
Minimum ½ pail back-up
Sodium Hydroxide Level
Minimum level of 1 foot
Sulfuric Acid Level
Minimum 1 back-up drum
Back-up buffer solutions? Yes ☐ No ☐

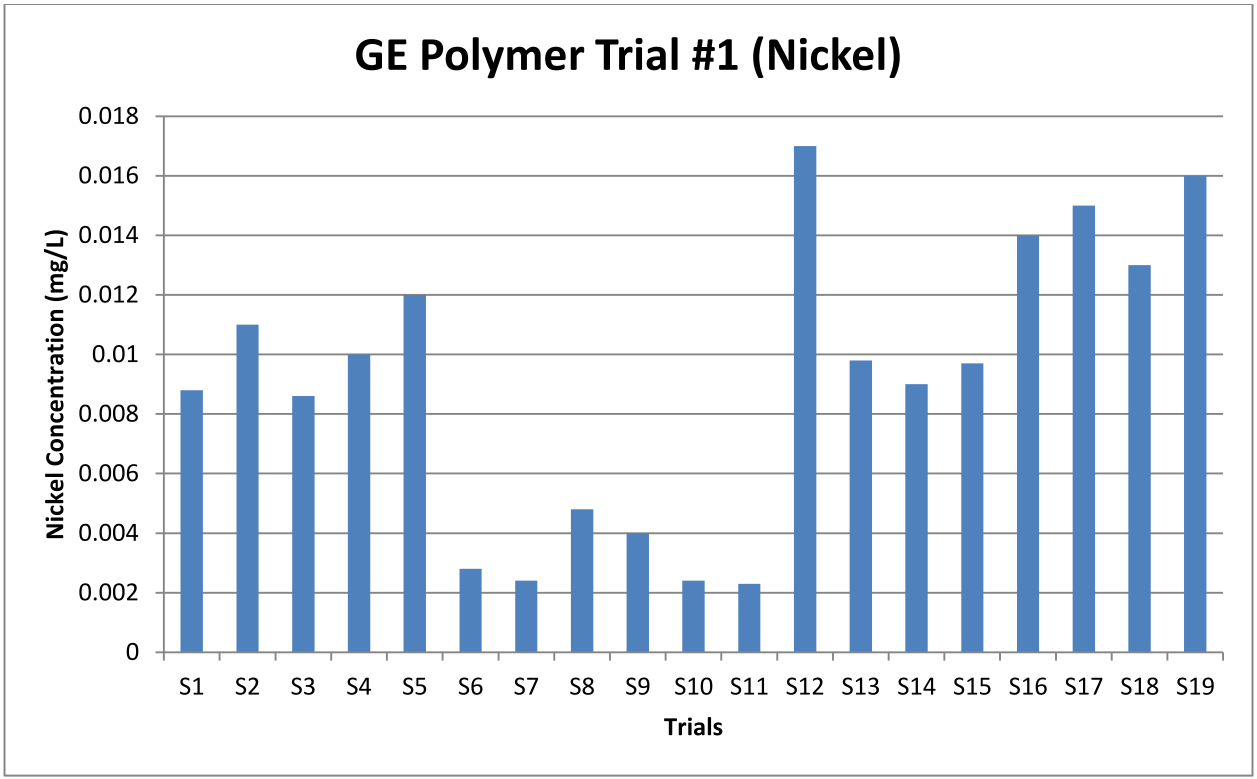
Visual Observations

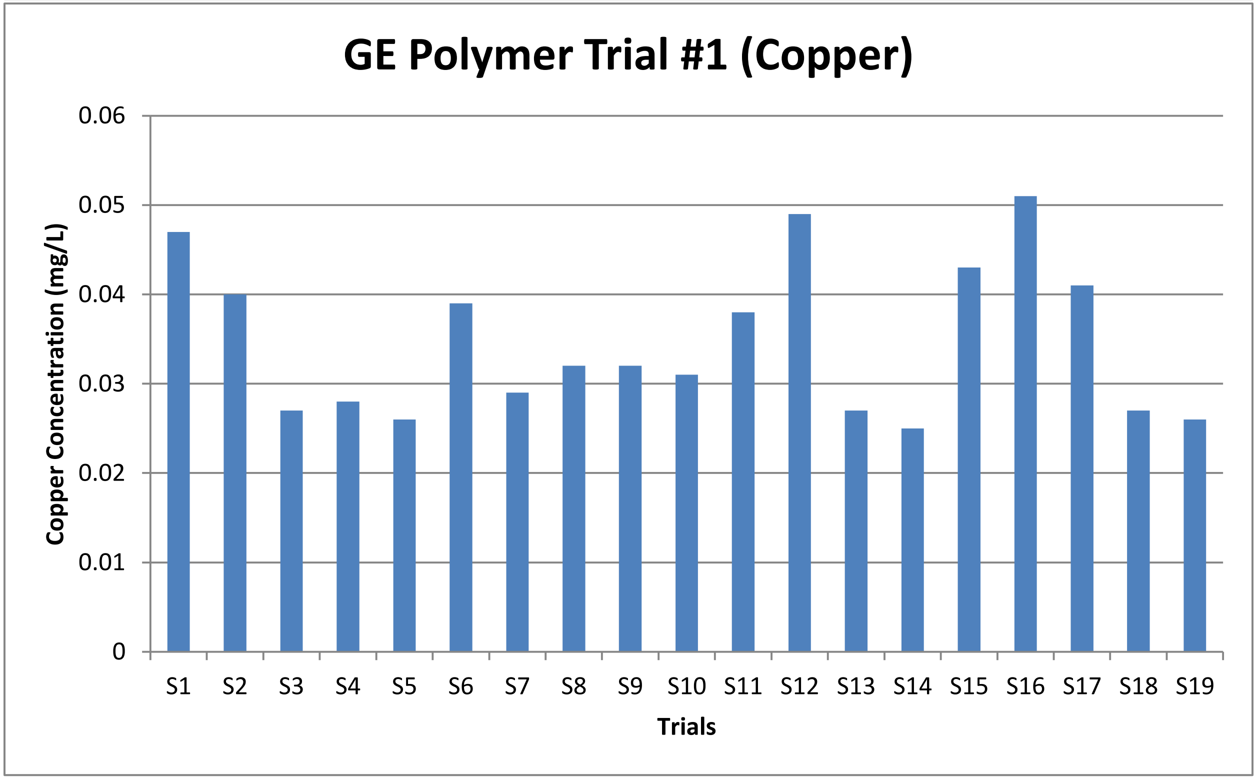
pH 1 tank observation
Mixer on? Yes ☐ No ☐
pH 2 tank observation
Mixer on? Yes ☐ No ☐
Flash tank observation
Mixer on? Yes ☐ No ☐
Flocc tank observation
Mixer on? Yes ☐ No ☐
Clarifier observation
Mixer on? Yes ☐ No ☐
Spills / Leaks Yes ☐ No ☐
Describe
General Comments

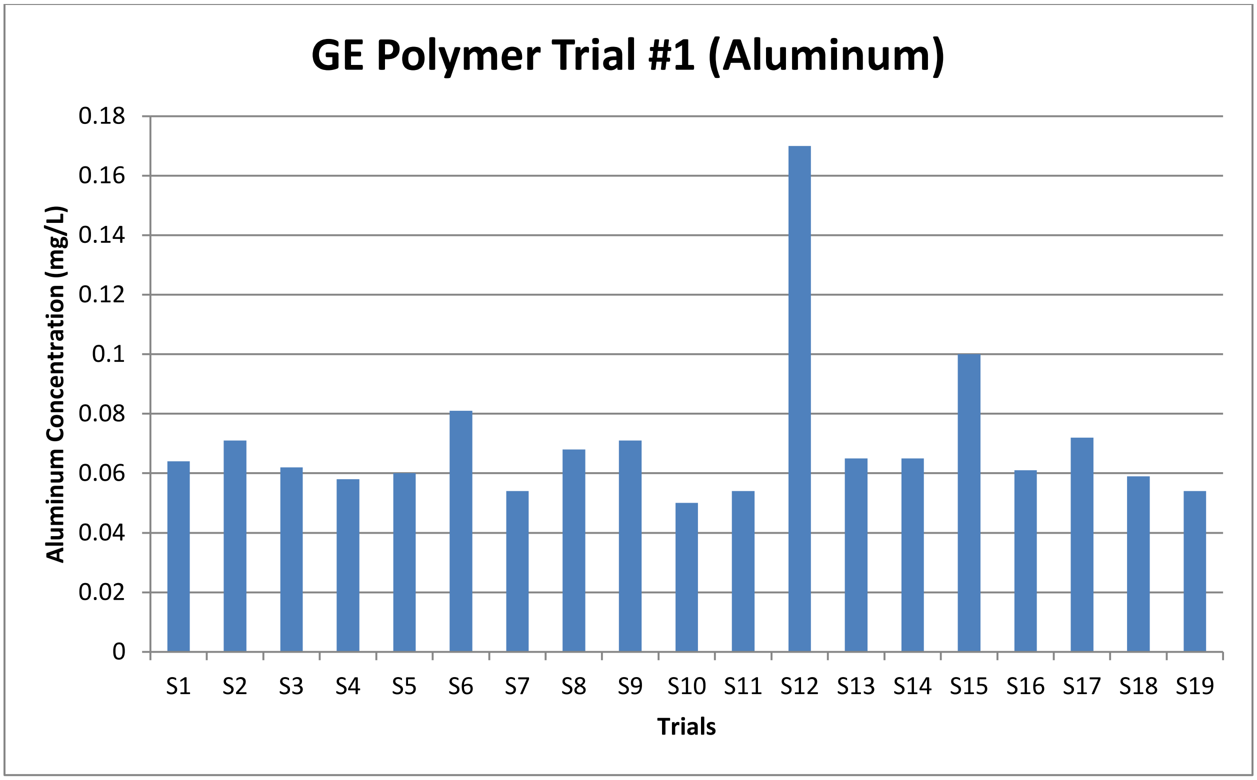
Appendix B: Polymer Testing Results (All Hazardous Metals)






GE Polymer Trial #1 (Nickel)
Nickel Concentration (mg/L)
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10
S11
S12
S13
S14
S15
S16
S17
S18
S19
Trials


GE Polymer Trial #1 (Copper)
Copper Concentration (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10
S11
S12
S13
S14
S15
S16
S17
S18
S19
Trials


GE Polymer Trial #1 (Aluminum)
Aluminum Concentration (mg/L)
0.18
0.16
0.14
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0.08
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0.04
0.02
0
S1
S2
S3
S4
S5
S6
S7
S8
S9
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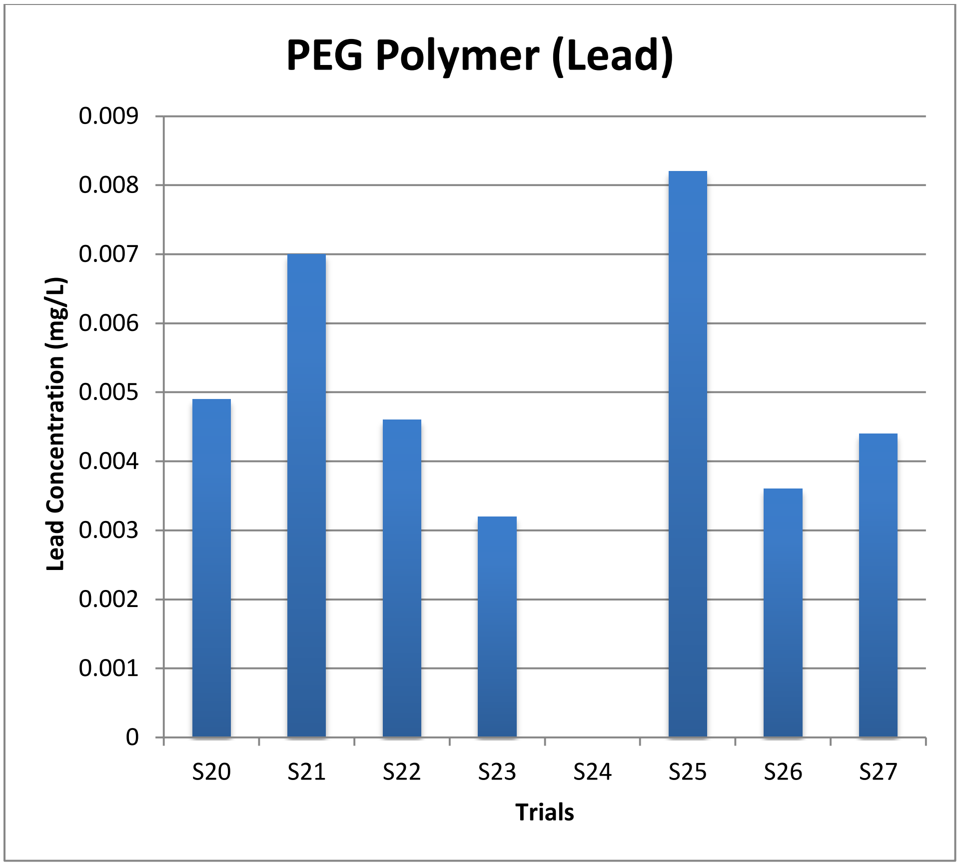
S11
S12
S13
S14
S15
S16
S17
S18
S19
Trials


PEG Polymer (Lead)
Lead Concentration (mg/L)
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0.006
0.005
0.004
0.003
0.002
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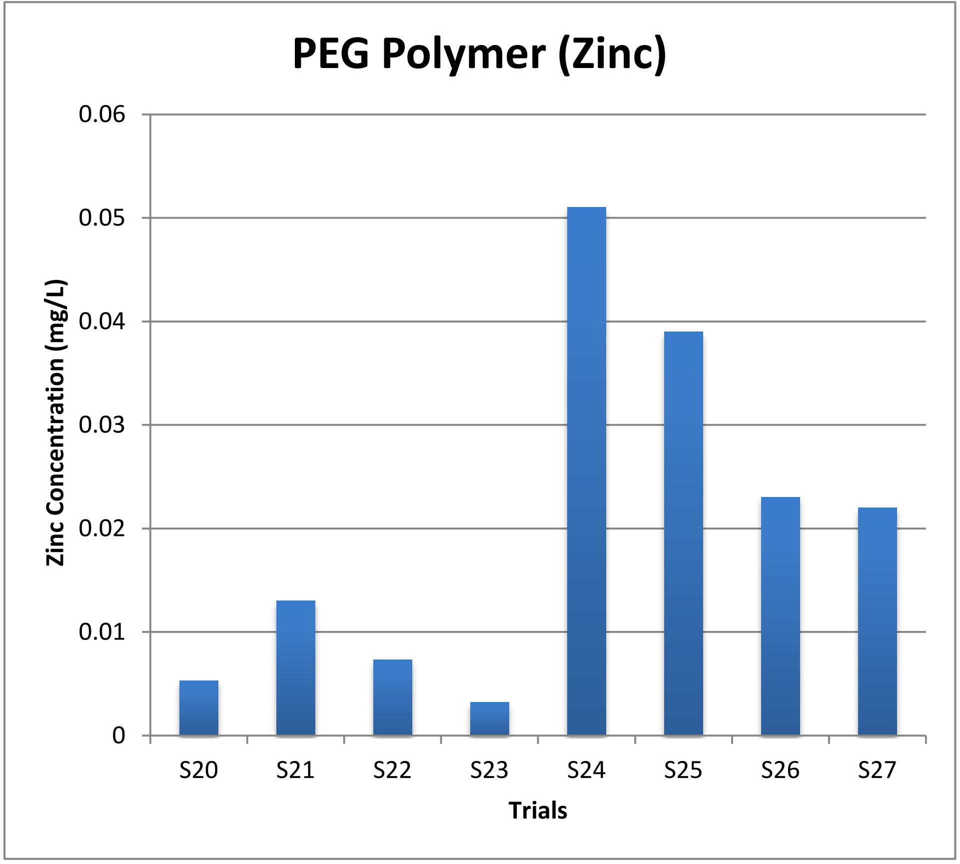
0
S20
S21
S22
S23
S24
S25
S26
S27
Trials


PEG Polymer (Zinc)
Zinc Concentration (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0
S20
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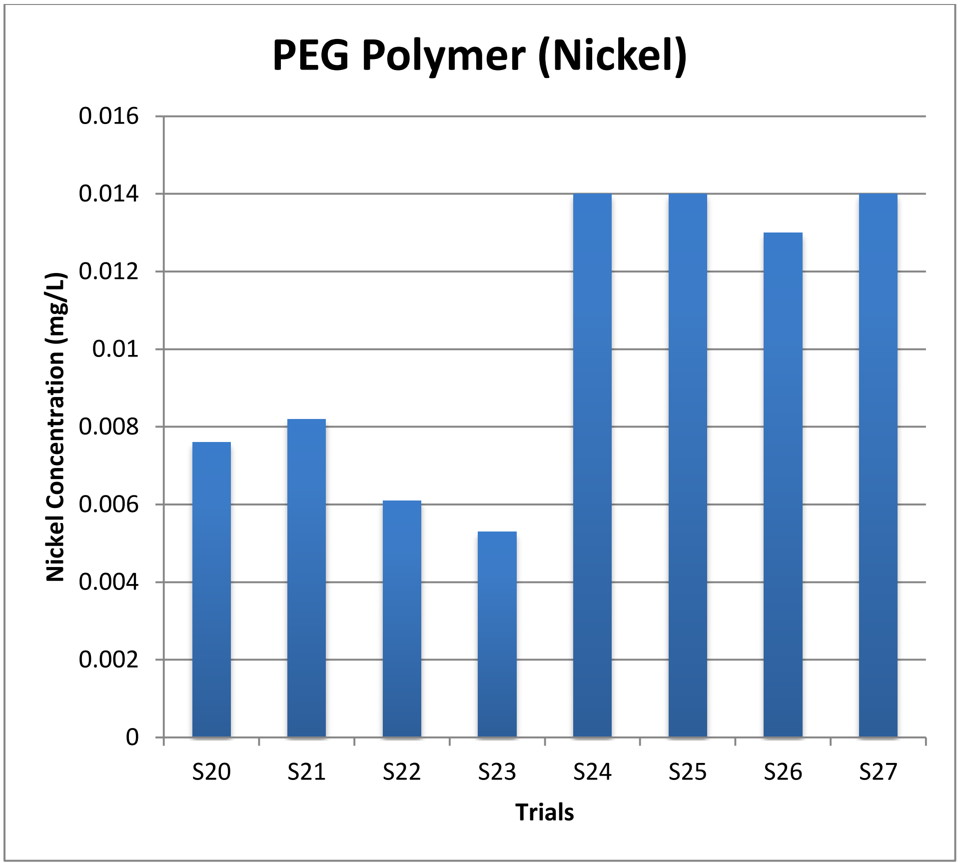
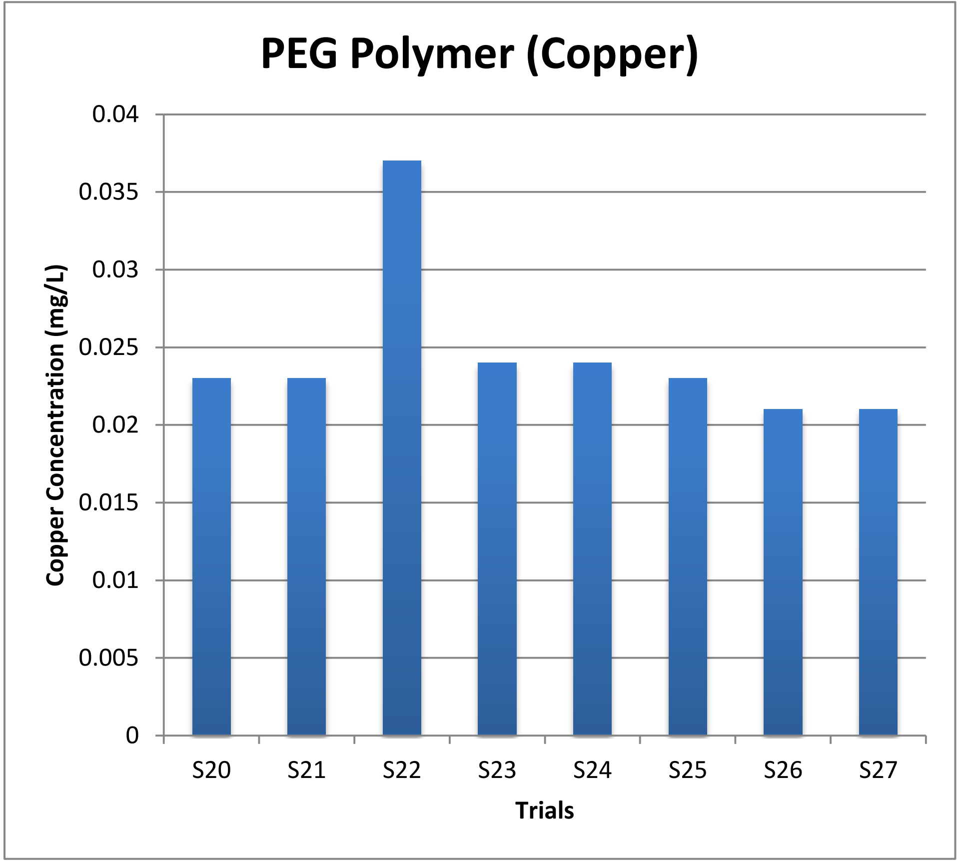
S23
S24
S25
S26
S27
Trials


PEG Polymer (Nickel)
Nickel Concentration (mg/L)
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
S20
S21
S22
S23
S24
S25
S26
S27
Trials


PEG Polymer (Copper)
Copper Concentration (mg/L)
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0.035
0.03
0.025
0.02
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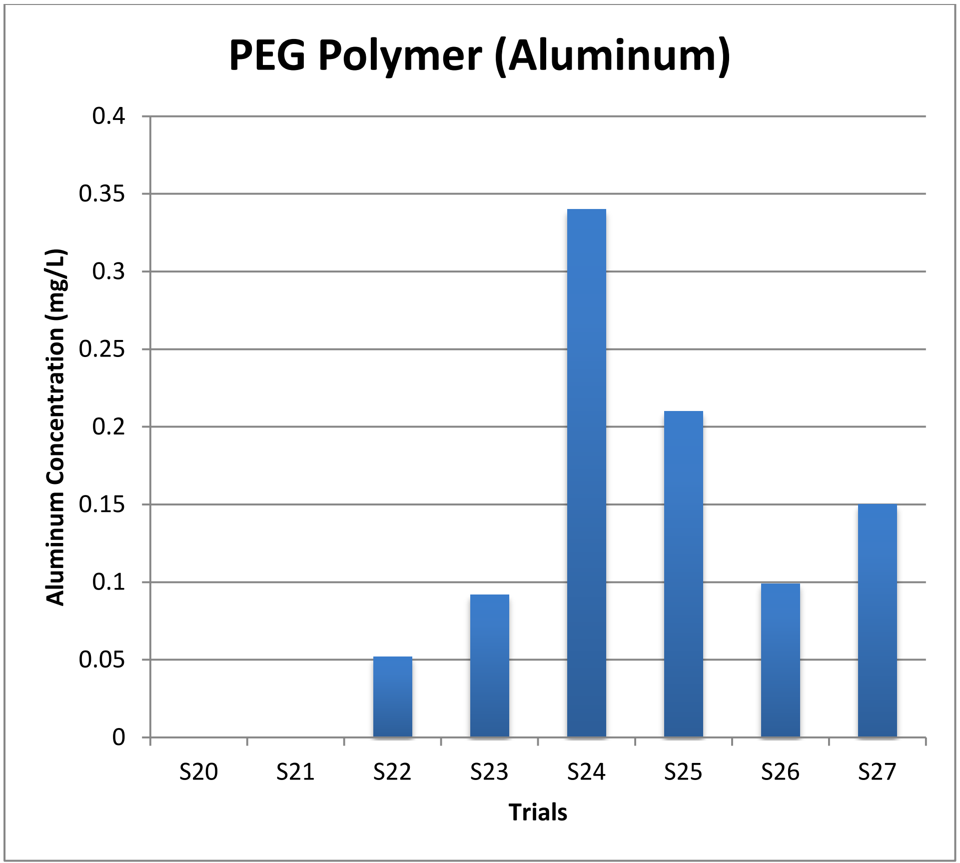
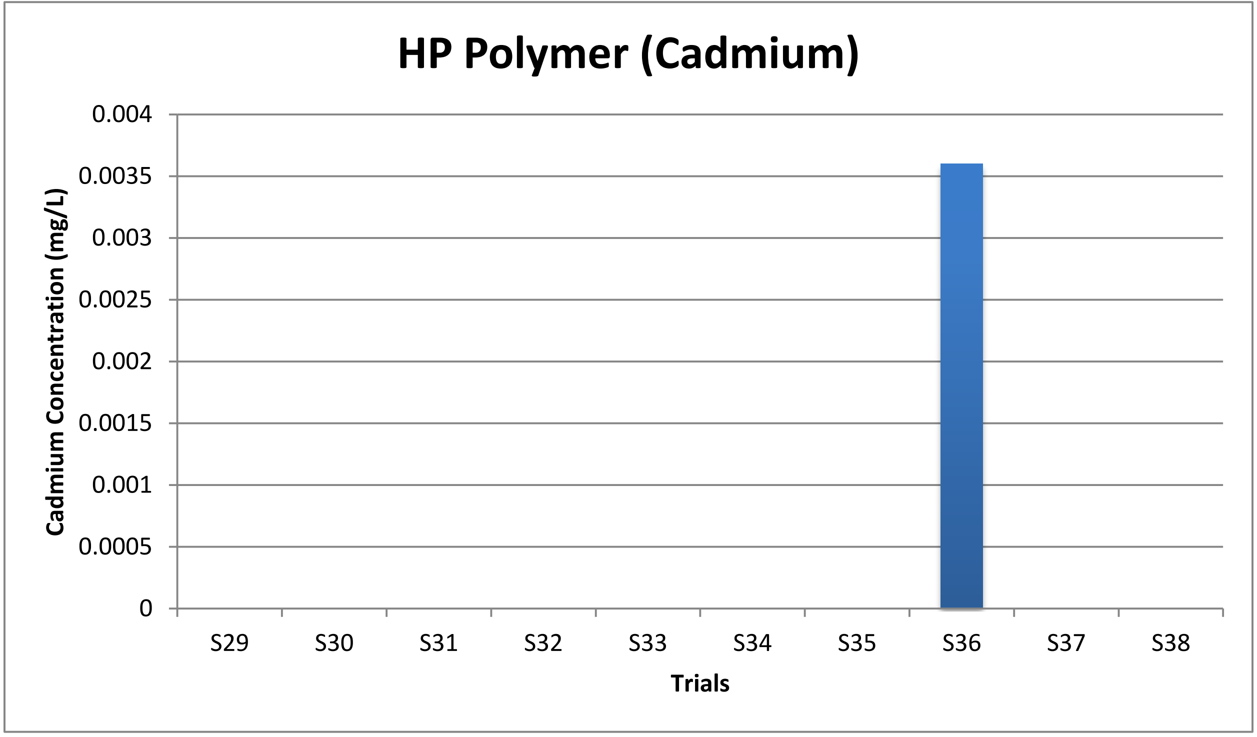
0.01
0.005
0
S20
S21
S22
S23
S24
S25
S26
S27
Trials


PEG Polymer (Aluminum)
Aluminum Concentration (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
S20
S21
S22
S23
S24
S25
S26
S27
Trials


HP Polymer (Cadmium)
Cadmium Concentration (mg/L)
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0.0035
0.003
0.0025
0.002
0.0015
0.001
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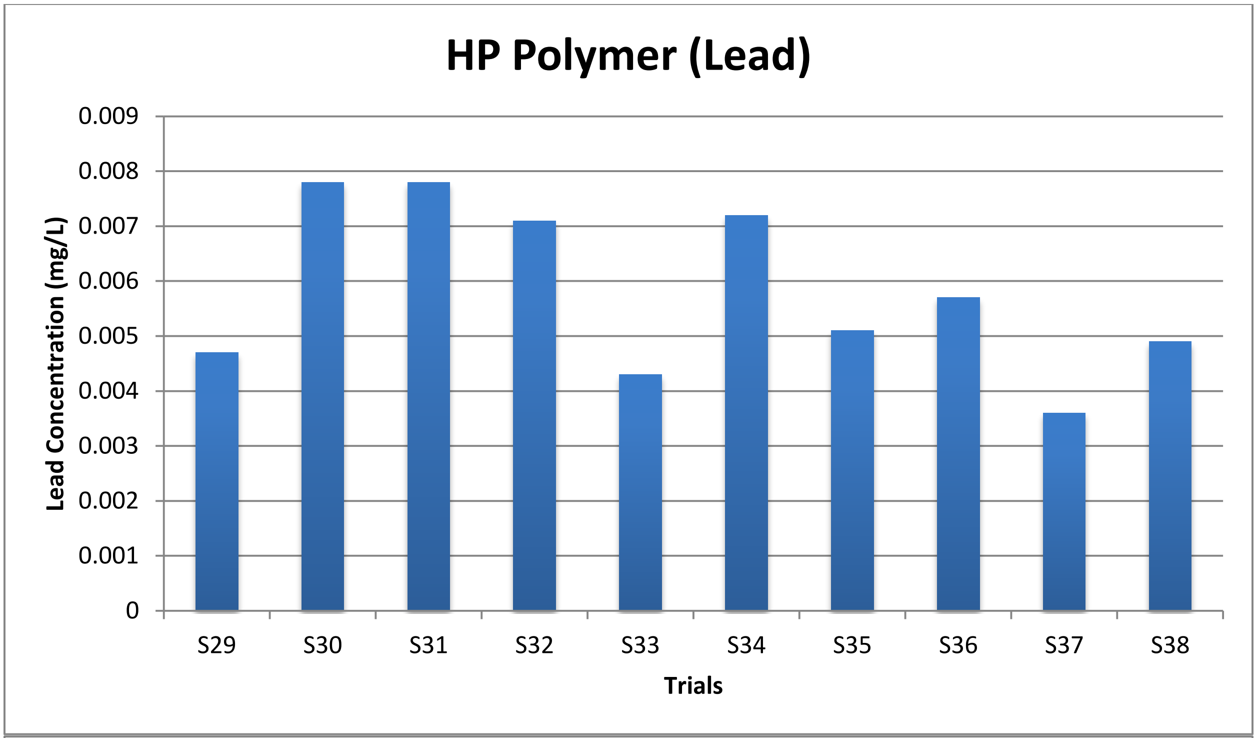
0
S29
S30
S31
S32
S33
S34
S35
S36
S37
S38
Trials


HP Polymer (Lead)
Lead Concentration (mg/L)
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0.008
0.007
0.006
0.005
0.004
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0.001
0
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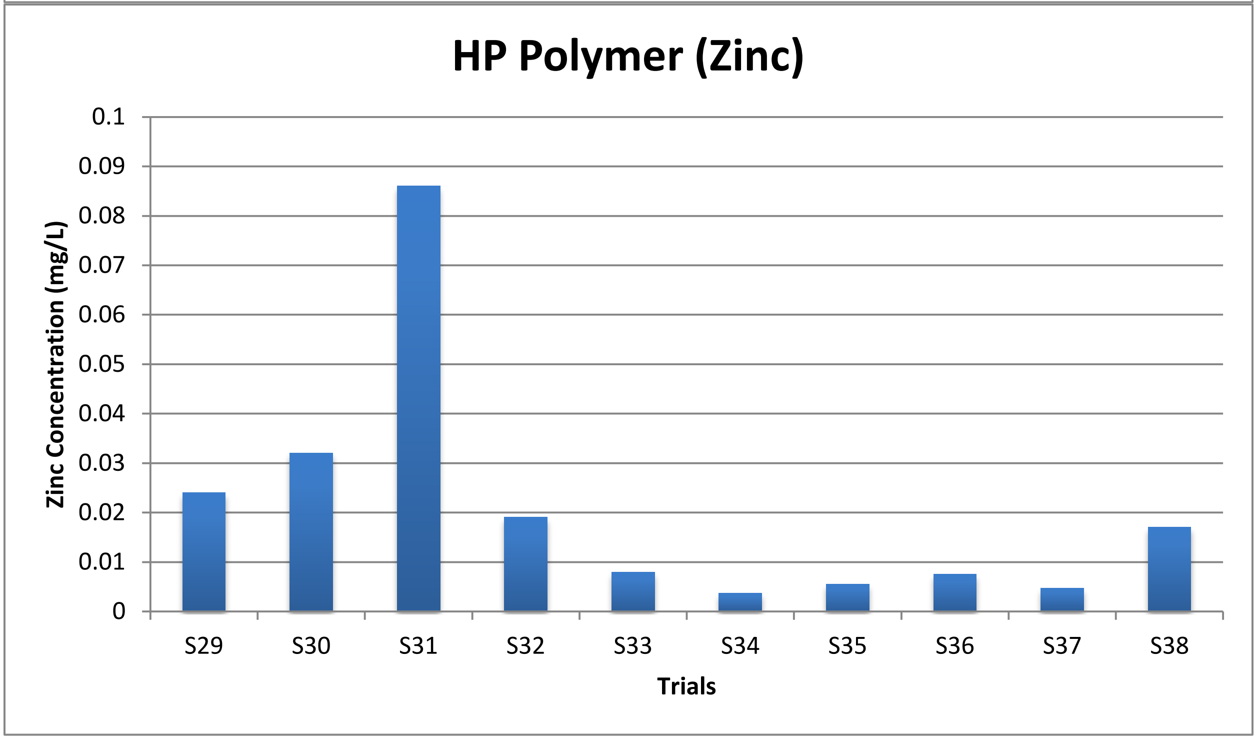
S30
S31
S32
S33
S34
S35
S36
S37
S38
Trials


HP Polymer (Zinc)
Zinc Concentration (mg/L)
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0.06
0.05
0.04
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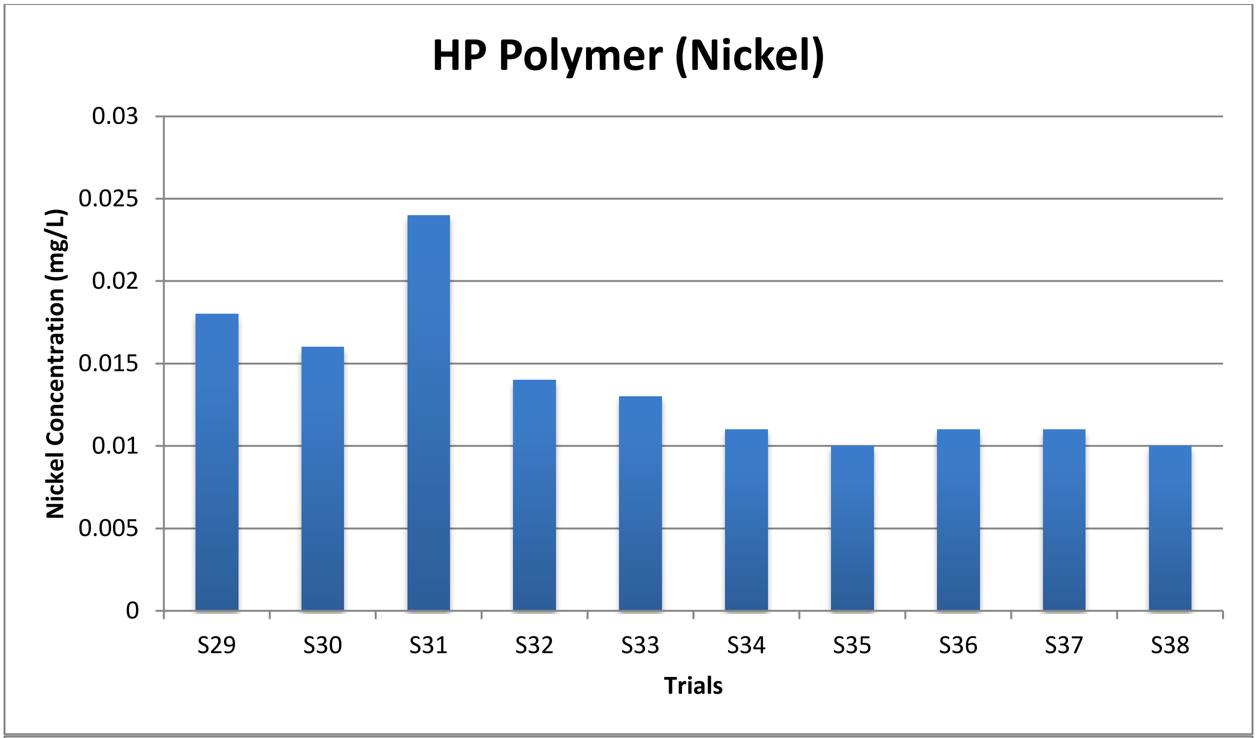
S33
S34
S35
S36
S37
S38
Trials


HP Polymer (Nickel)
Nickel Concentration (mg/L)
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0.025
0.02
0.015
0.01
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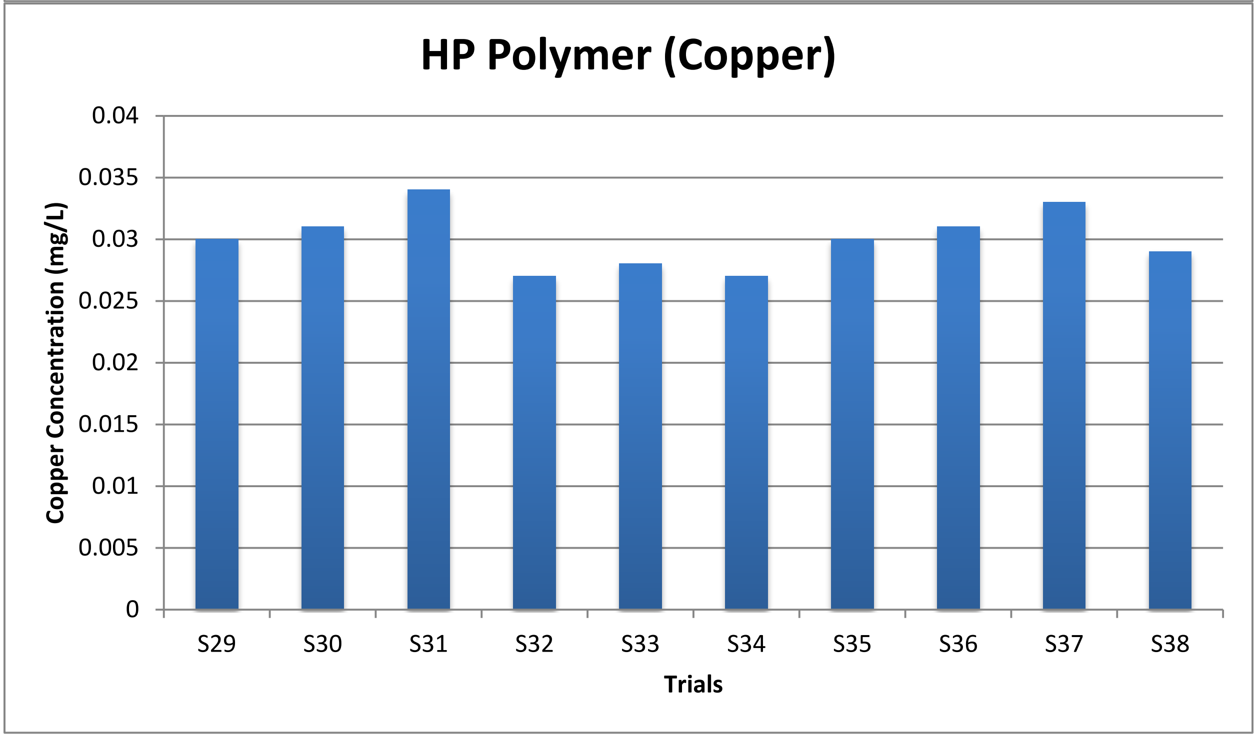
0
S29
S30
S31
S32
S33
S34
S35
S36
S37
S38
Trials


HP Polymer (Copper)
Copper Concentration (mg/L)
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0.035
0.03
0.025
0.02
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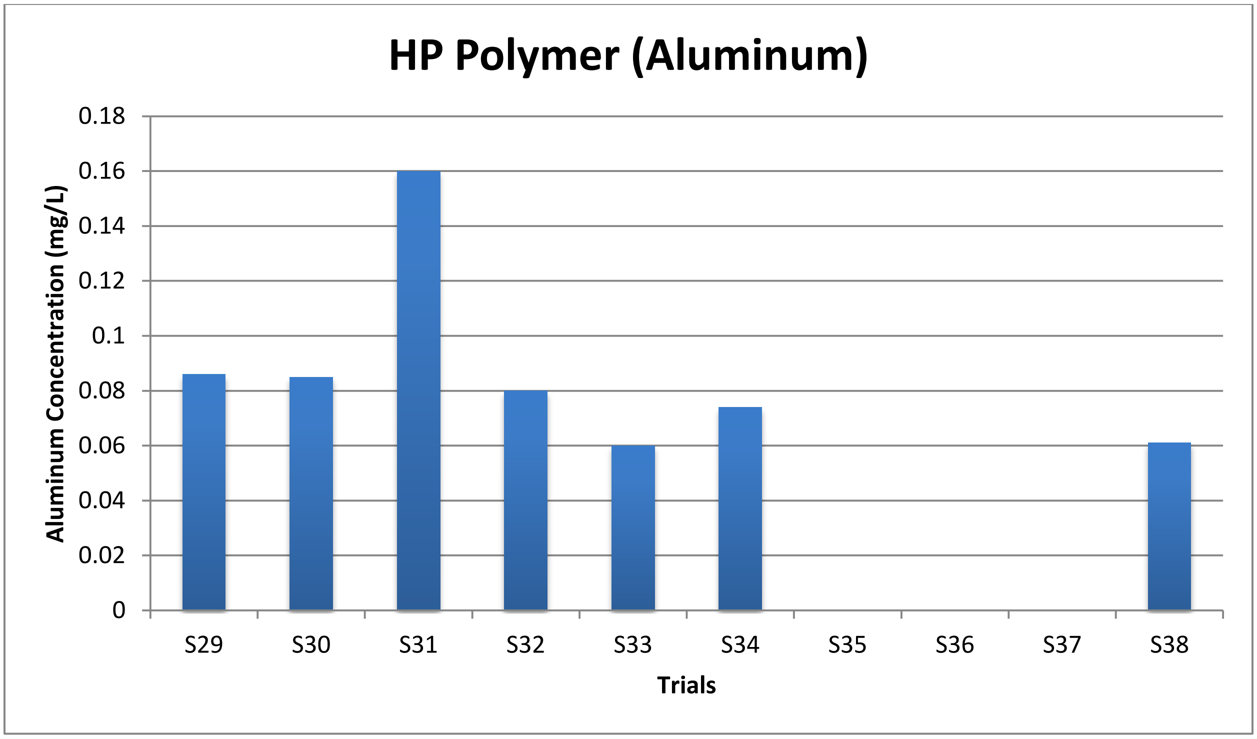
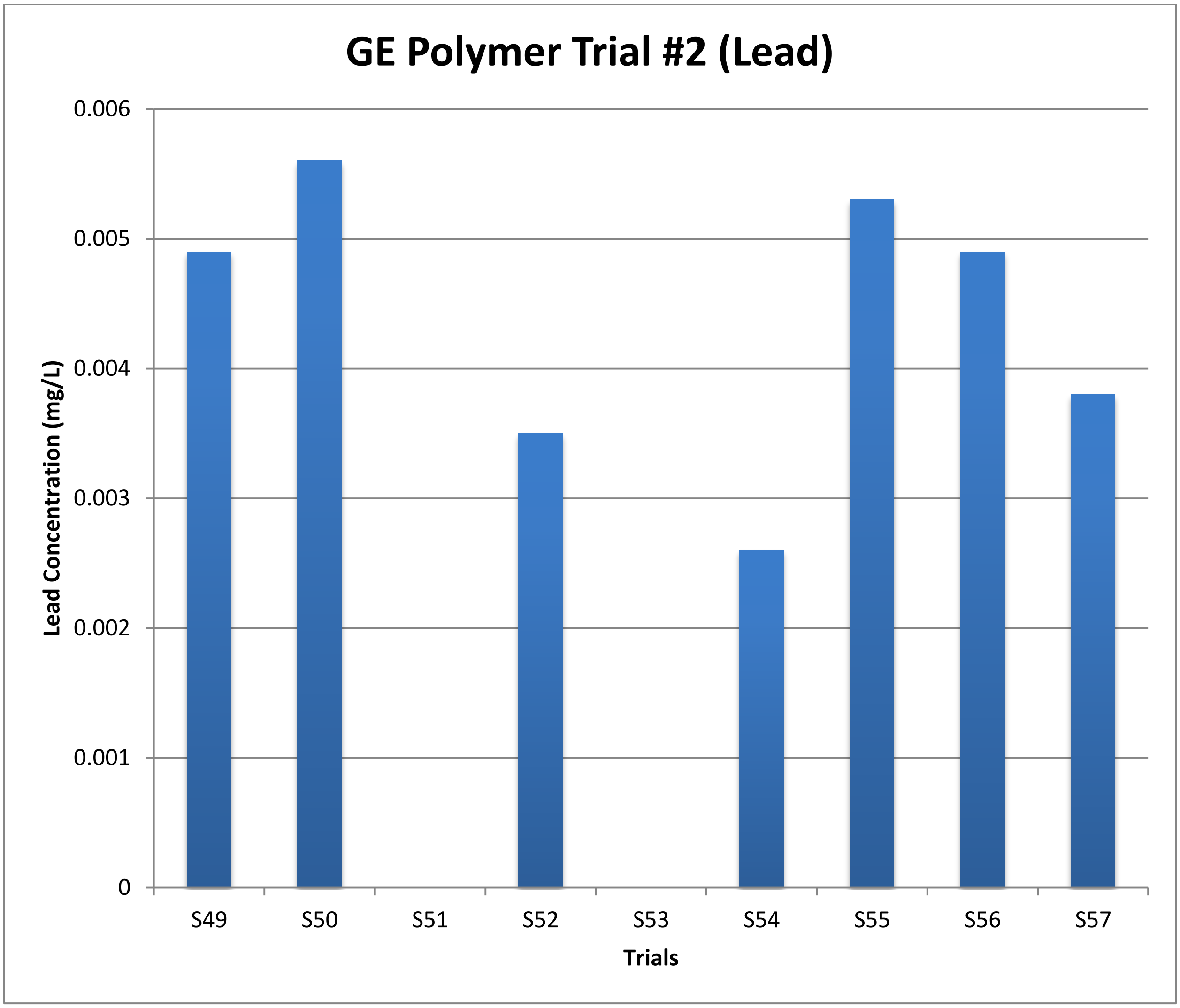
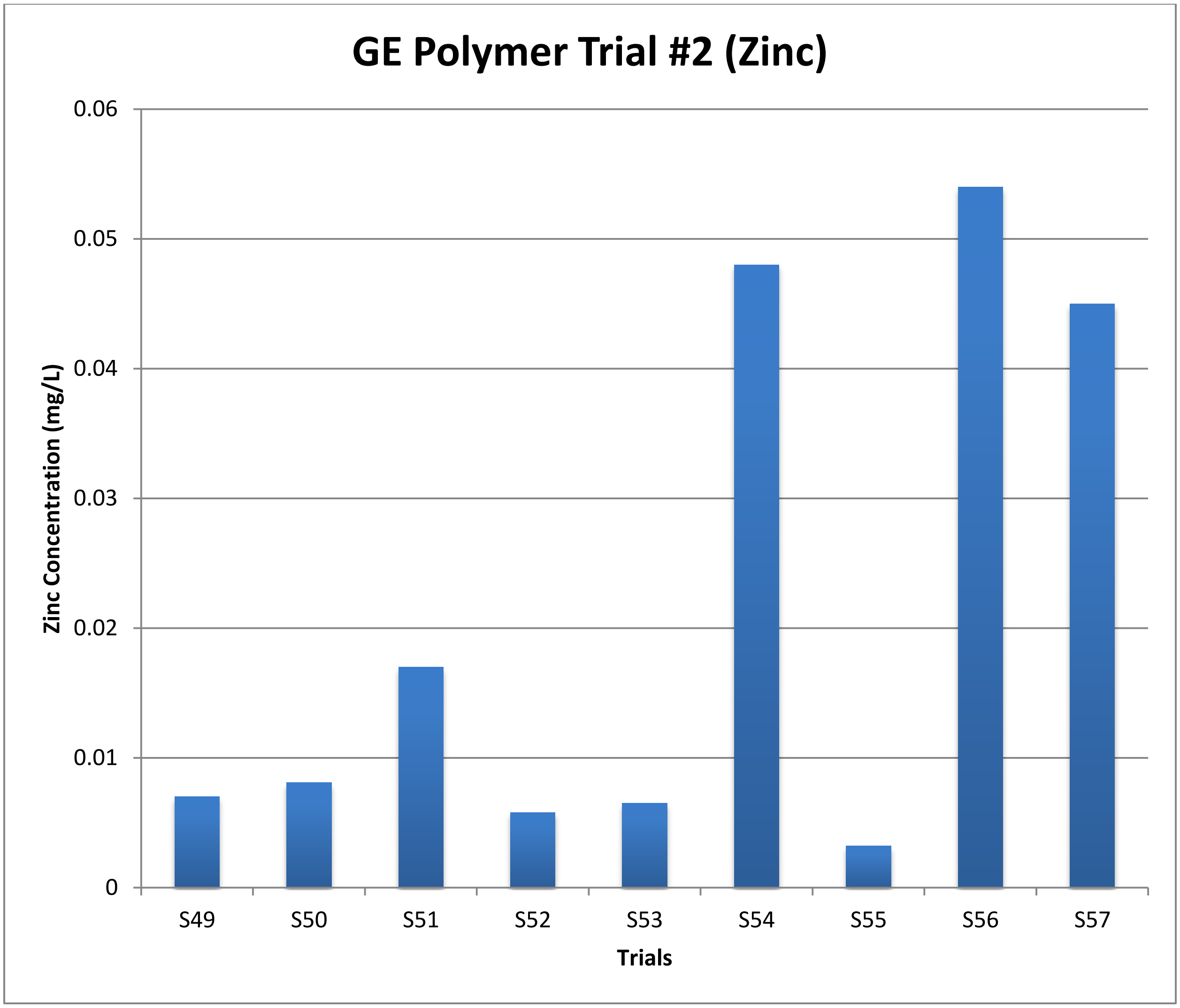
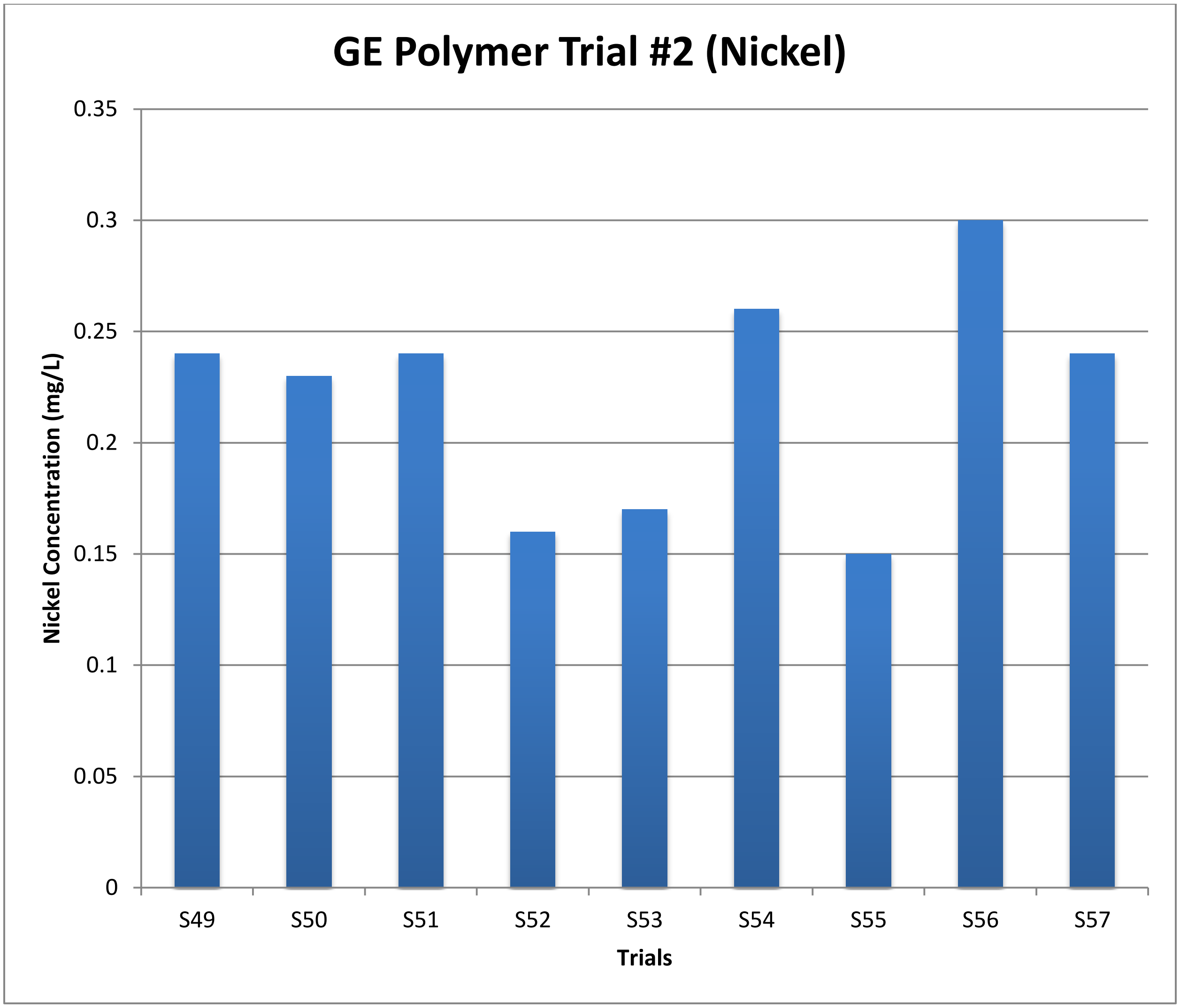
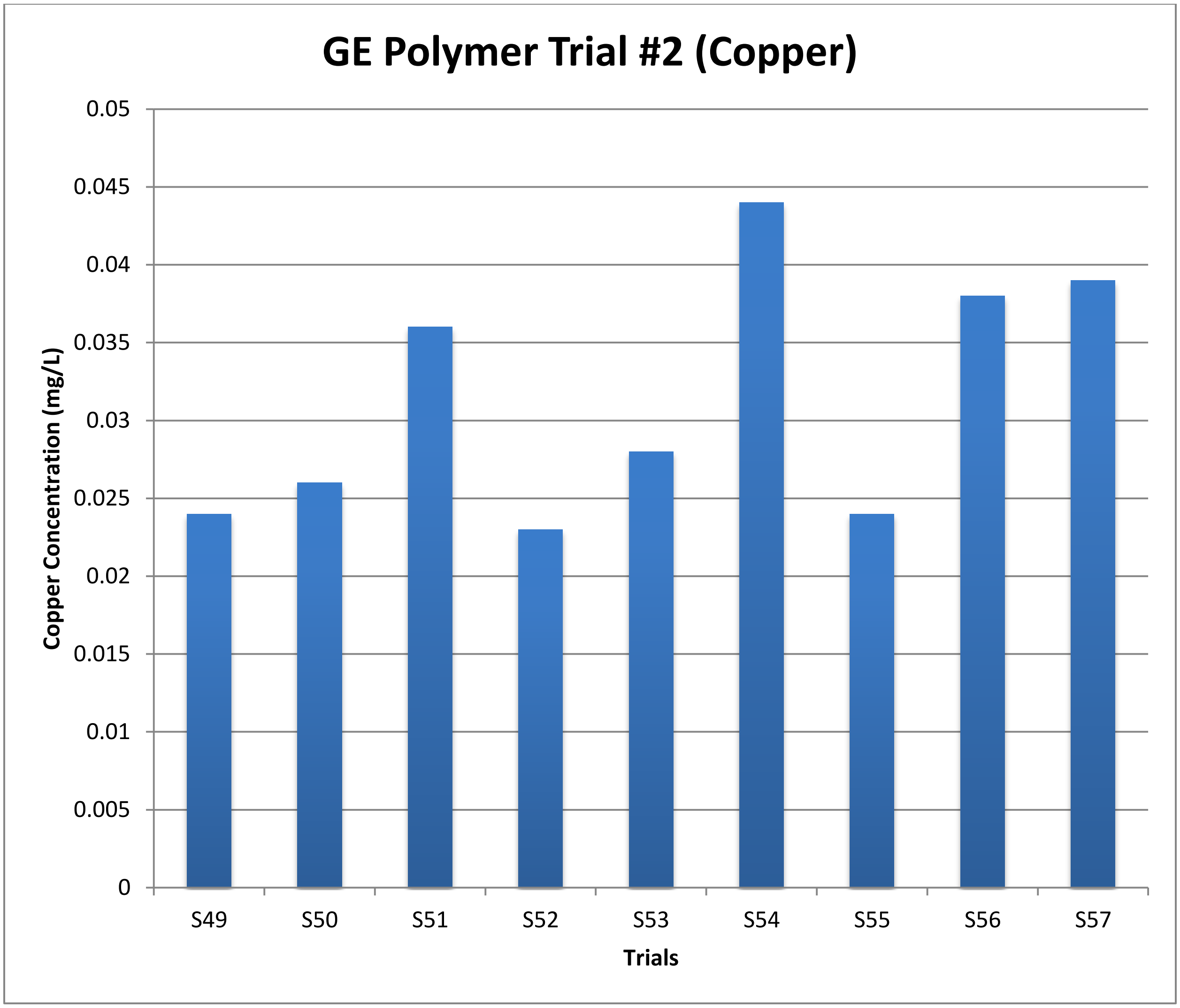
0.01
0.005
0
S29
S30
S31
S32
S33
S34
S35
S36
S37
S38
Trials

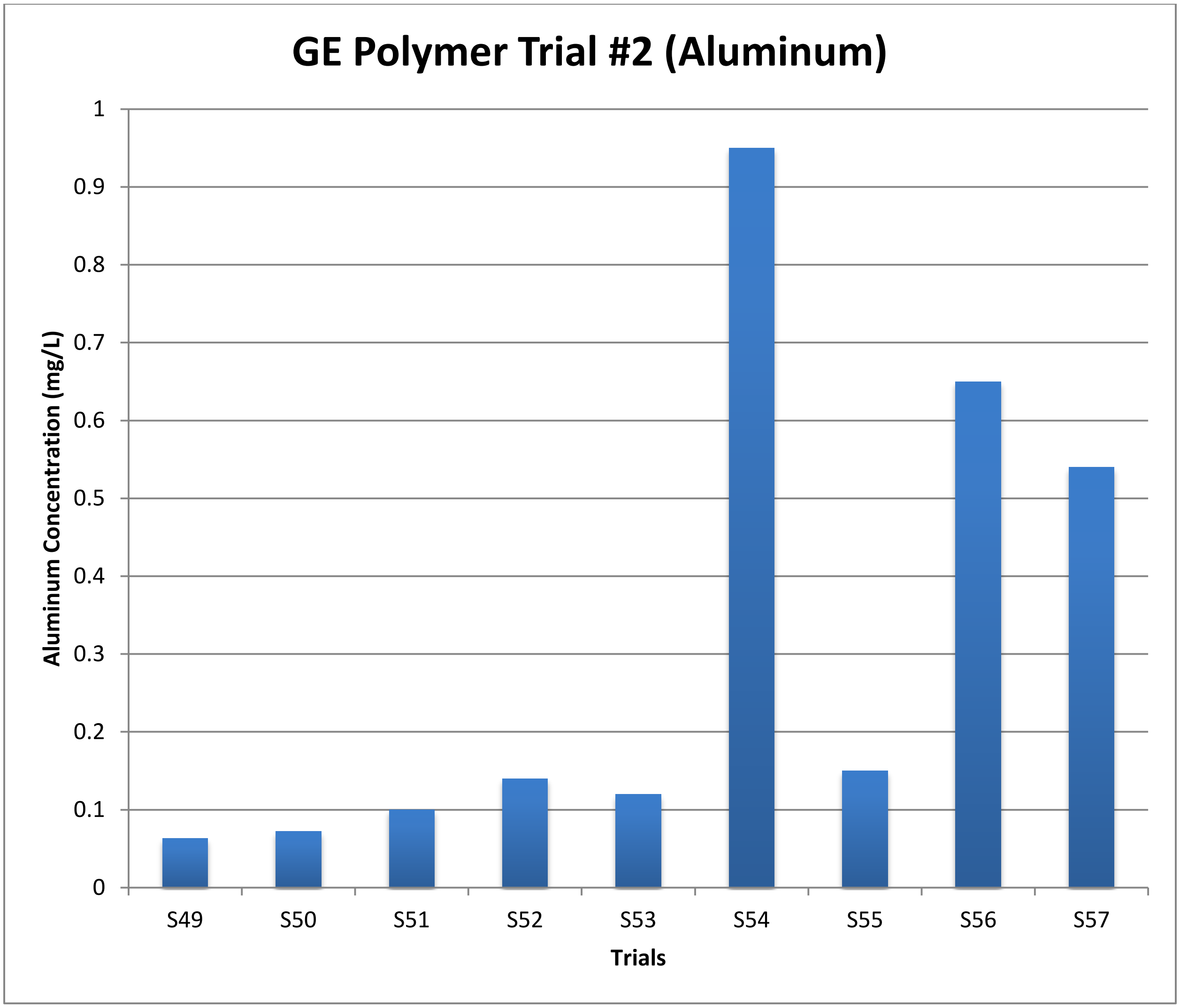

HP Polymer (Aluminum)
Aluminum Concentration (mg/L)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
S29
S30
S31
S32
S33
S34
S35
S36
S37
S38
Trials


GE Polymer Trial #2 (Lead)
Lead Concentration (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
S49
S50
S51
S52
S53
S54
S55
S56
S57
Trials


GE Polymer Trial #2 (Zinc)
Zinc Concentration (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0
S49
S50
S51
S52
S53
S54
S55
S56
S57
Trials


GE Polymer Trial #2 (Nickel)
Nickel Concentration (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
S49
S50
S51
S52
S53
S54
S55
S56
S57
Trials


GE Polymer Trial #2 (Copper)
Copper Concentration (mg/L)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
S49
S50
S51
S52
S53
S54
S55
S56
S57
Trials


GE Polymer Trial #2 (Aluminum)
Aluminum Concentration (mg/L)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
S49
S50
S51
S52
S53
S54
S55
S56
S57
Trials

Appendix C: Material Safety Data Sheets

Aluminum

ScienceLab.com
Chemicals & Laboratory Equipment

Health	1
Fire	0
Reactivity	0
Personal Protection	B

Material Safety Data Sheet
Aluminum MSDS

Section 1: Chemical Product and Company Identification

Product Name: Aluminum

Catalog Codes: SLA4735, SLA2389, SLA3895, SLA1549, SLA3055, SLA4558, SLA2212, SLA3715

CAS#: 7429-90-5

RTECS: BD0330000

TSCA: TSCA 8(b) inventory: Aluminum

CI#: Not applicable.

Synonym: Aluminum metal pellets; Aluminum metal sheet; Aluminum metal shot; Aluminum metal wire

Chemical Name: Aluminum

Chemical Formula: Al

Contact Information:

Sciencelab.com, Inc.
14025 Smith Rd.
Houston, Texas 77396

US Sales: **1-800-901-7247**
International Sales: **1-281-441-4400**

Order Online: ScienceLab.com

CHEMTREC (24HR Emergency Telephone), call: 1-800-424-9300

International CHEMTREC, call: 1-703-527-3887

For non-emergency assistance, call: 1-281-441-4400

Section 2: Composition and Information on Ingredients

Composition:

Name	CAS #	% by Weight
Aluminum	7429-90-5	100

Toxicological Data on Ingredients: Aluminum LD50: Not available. LC50: Not available.

Section 3: Hazards Identification

Potential Acute Health Effects:
Slightly hazardous in case of skin contact (irritant). Non-irritating to the eyes. Non-hazardous in case of ingestion.

Potential Chronic Health Effects:
CARCINOGENIC EFFECTS: Not available. MUTAGENIC EFFECTS: Not available. TERATOGENIC EFFECTS: Not available. DEVELOPMENTAL TOXICITY: Not available. The substance is toxic to lungs. Repeated or prolonged exposure to the substance can produce target organs damage. Repeated exposure to a highly toxic material may produce general deterioration of health by an accumulation in one or many human organs.

Section 4: First Aid Measures

Eye Contact:

p. 1

Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Get medical attention if irritation occurs.

Skin Contact: Wash with soap and water. Cover the irritated skin with an emollient. Get medical attention if irritation develops.

Serious Skin Contact: Not available.

Inhalation:
If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention immediately.

Serious Inhalation: Not available.

Ingestion:
Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. If large quantities of this material are swallowed, call a physician immediately. Loosen tight clothing such as a collar, tie, belt or waistband.

Serious Ingestion: Not available.

Section 5: Fire and Explosion Data

Flammability of the Product: Non-flammable.

Auto-Ignition Temperature: Not available.

Flash Points: Not available.

Flammable Limits: Not available.

Products of Combustion: Some metallic oxides.

Fire Hazards in Presence of Various Substances: Not available.

Explosion Hazards in Presence of Various Substances:
Risks of explosion of the product in presence of mechanical impact: Not available. Risks of explosion of the product in presence of static discharge: Not available.

Fire Fighting Media and Instructions:
SMALL FIRE: Use DRY chemical powder. LARGE FIRE: Use water spray, fog or foam. Do not use water jet.

Special Remarks on Fire Hazards: Not available.

Special Remarks on Explosion Hazards: Not available.

Section 6: Accidental Release Measures

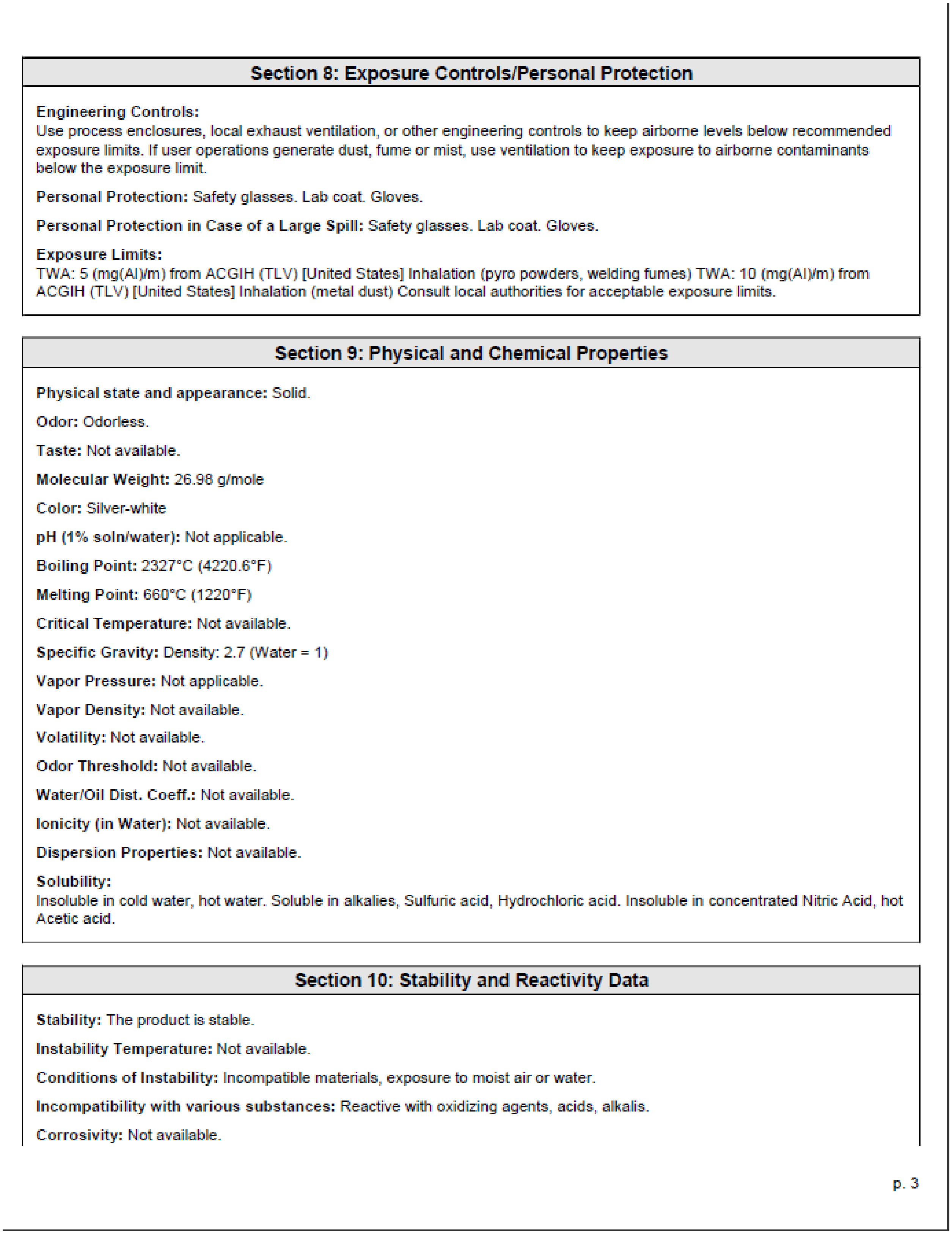
Small Spill:
Use appropriate tools to put the spilled solid in a convenient waste disposal container. Finish cleaning by spreading water on the contaminated surface and dispose of according to local and regional authority requirements.

Large Spill:
Use a shovel to put the material into a convenient waste disposal container. Finish cleaning by spreading water on the contaminated surface and allow to evacuate through the sanitary system.

Section 7: Handling and Storage

Precautions:
Do not ingest. Wear suitable protective clothing. If ingested, seek medical advice immediately and show the container or the label. Keep away from incompatibles such as oxidizing agents, acids, alkalis.

Storage: Keep container tightly closed. Keep container in a cool, well-ventilated area. Moisture sensitive.



Section 8: Exposure Controls/Personal Protection

Engineering Controls:
Use process enclosures, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. If user operations generate dust, fume or mist, use ventilation to keep exposure to airborne contaminants below the exposure limit.

Personal Protection: Safety glasses. Lab coat. Gloves.

Personal Protection in Case of a Large Spill: Safety glasses. Lab coat. Gloves.

Exposure Limits:
TWA: 5 (mg(Al)/m) from ACGIH (TLV) [United States] Inhalation (pyro powders, welding fumes) TWA: 10 (mg(Al)/m) from ACGIH (TLV) [United States] Inhalation (metal dust) Consult local authorities for acceptable exposure limits.

Section 9: Physical and Chemical Properties

Physical state and appearance: Solid.

Odor: Odorless.

Taste: Not available.

Molecular Weight: 26.98 g/mole

Color: Silver-white

pH (1% soln/water): Not applicable.

Boiling Point: 2327°C (4220.6°F)

Melting Point: 660°C (1220°F)

Critical Temperature: Not available.

Specific Gravity: Density: 2.7 (Water = 1)

Vapor Pressure: Not applicable.

Vapor Density: Not available.

Volatility: Not available.

Odor Threshold: Not available.

Water/Oil Dist. Coeff.: Not available.

Ionicity (in Water): Not available.

Dispersion Properties: Not available.

Solubility:
Insoluble in cold water, hot water. Soluble in alkalies, Sulfuric acid, Hydrochloric acid. Insoluble in concentrated Nitric Acid, hot Acetic acid.

Section 10: Stability and Reactivity Data

Stability: The product is stable.

Instability Temperature: Not available.

Conditions of Instability: Incompatible materials, exposure to moist air or water.

Incompatibility with various substances: Reactive with oxidizing agents, acids, alkalis.

Corrosivity: Not available.

Special Remarks on Reactivity:
Moisture sensitive. Aluminum reacts vigorously with Sodium Hydroxide. Aluminum is also incompatible with strong oxdizers, acids, chromic anhydride, iodine, carbon disulfide, methyl chloride, and halogenated hydrocarbons, acid chlorides, ammonium nitrate, ammonium persulfate, antimony, arsenic oxides, barium bromate, barium chlorate, barium iodate, metal salts

Special Remarks on Corrosivity:
In moist air, oxide film forms which protects metal from corrosion. Aluminum is strongly electropositive so that it corrodes rapidly in contact with other metals.

Polymerization: Will not occur.

Section 11: Toxicological Information

Routes of Entry: Not available.

Toxicity to Animals: Not available

Chronic Effects on Humans: Not available.

Other Toxic Effects on Humans:
Slightly hazardous in case of skin contact (irritant). Non-hazardous in case of ingestion. Non-hazardous in case of inhalation.

Special Remarks on Toxicity to Animals: Not available.

Special Remarks on Chronic Effects on Humans: Not available.

Special Remarks on other Toxic Effects on Humans:
Acute Potential Health Effects: Skin: Exposure to aluminum may cause skin irritation. Eyes: Not expected to be a hazard unless aluminum dust particles are present. Exposure to aluminum dust may cause eye irritation by mechanical action. Aluminum particles deposited in the eye are generally innocous. Inhalation: Not expected to be an inhalation hazard unless it is heatedor if aluminum dust is present It heated or in dust form, it may cause respiratory tract irritation. Heating Aluminum can release Aluminum Oxide fumes and cause fume metal fever when inhaled. This is a flu-like illness with symptoms of metallic taste, fever, chills, aches, chest tightness, and cough. Ingestion: Acute aluminum toxicity is unlikely. Chronic Potential Health Effects: Skin: Contact dermatitis occurs rarely after aluminum exposure. Most cases of aluminum toxicity in humans are in one of two categories: patients with chronic renal failure, or people exposed to aluminum fumes or dust in the workplace. The main source of aluminum in people with chronic renal failure was in the high aluminum content of the water for the dialysate used for dialysis in the 1970's. Even though this problem was recognized and corrected, aluminum toxicity continues to occur in some individuals with renal who chronically ingest aluminum-containing phosphate binders or antacids. Inhalation: Chronic exposure to aluminum dust may cause dyspnea, cough, asthma, chronic obstructive lung disease, pulmonary fibrosis, pneumothorax, pneumoconiosis, encephalopathy, weakness, incoordination and epileptiform seizures and other neurological symptoms similar to that described for chronic ingestion. Hepatic necrosis is also a reported effect of exposure to airborne particulates carrying aluminum. Ingestion: Chronic ingestion of aluminum may cause Aluminum Related Bone Disease or aluminum-induced Osteomalacia with fracturing Osteodystrophy, microcytic anemia, weakness, fatigue, visual and auditory hallucinations, memory loss, speech and language impairment (dysarthria, stuttering, stammering, anomia, hypofluency, aphasia and eventually, mutism), epileptic seizures(focal or grand mal), motor disturbance(tremors, myoclonic jerks, ataxia, convulsions, asterixis, motor apraxia, muscle fatigue), and dementia (personality changes, altered mood, depression, diminished alertness, lethargy, 'clouding of the sensorium', intellectual deterioration, obtundation, coma), and altered EEG.

Section 12: Ecological Information

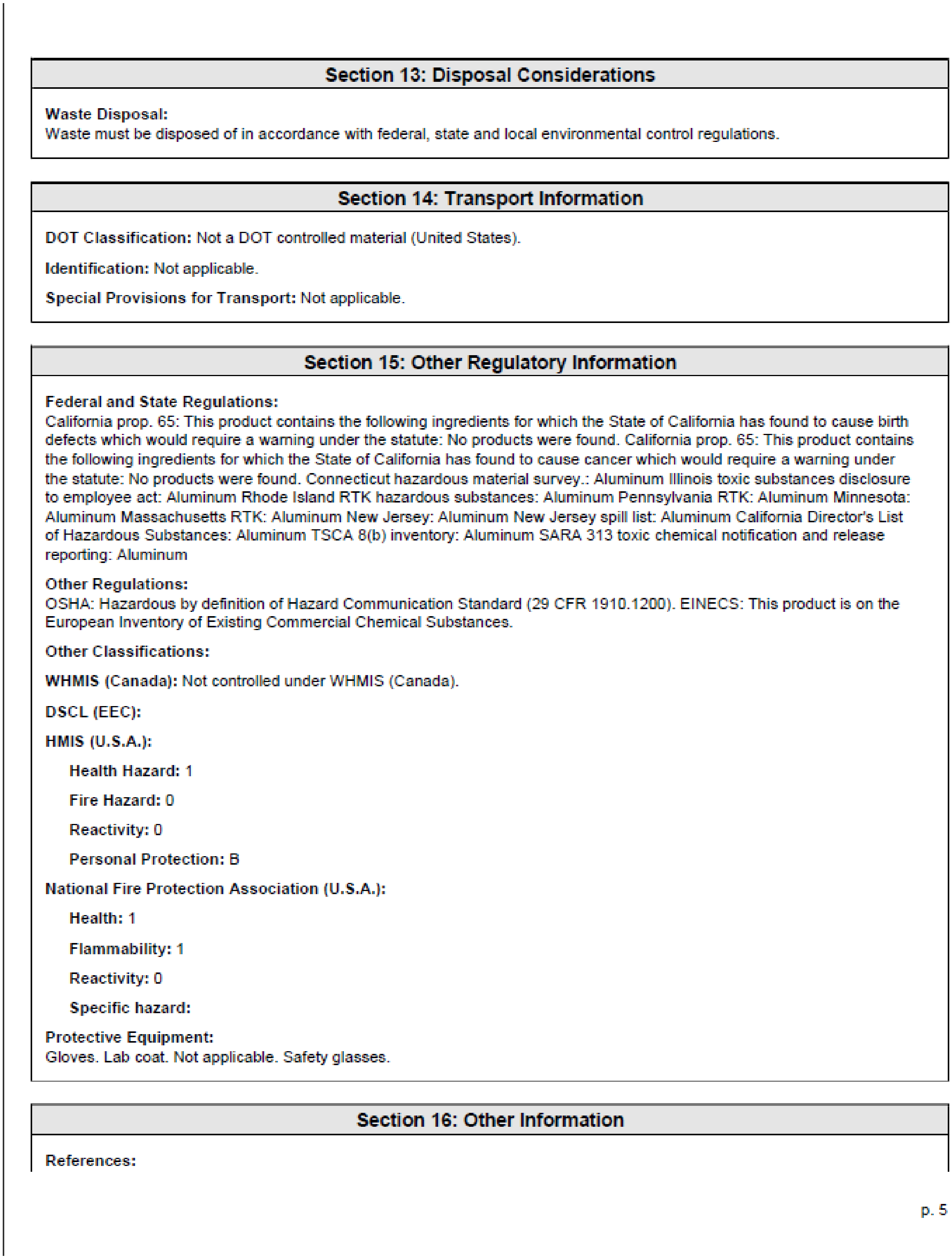
Ecotoxicity: Not available.

BOD5 and COD: Not available.

Products of Biodegradation:
Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

Toxicity of the Products of Biodegradation: The products of degradation are less toxic than the product itself.

Special Remarks on the Products of Biodegradation: Not available.



Section 13: Disposal Considerations

Waste Disposal:
Waste must be disposed of in accordance with federal, state and local environmental control regulations.

Section 14: Transport Information

DOT Classification: Not a DOT controlled material (United States).

Identification: Not applicable.

Special Provisions for Transport: Not applicable.

Section 15: Other Regulatory Information

Federal and State Regulations:
California prop. 65: This product contains the following ingredients for which the State of California has found to cause birth defects which would require a warning under the statute: No products were found. California prop. 65: This product contains the following ingredients for which the State of California has found to cause cancer which would require a warning under the statute: No products were found. Connecticut hazardous material survey.: Aluminum Illinois toxic substances disclosure to employee act: Aluminum Rhode Island RTK hazardous substances: Aluminum Pennsylvania RTK: Aluminum Minnesota: Aluminum Massachusetts RTK: Aluminum New Jersey: Aluminum New Jersey spill list: Aluminum California Director's List of Hazardous Substances: Aluminum TSCA 8(b) inventory: Aluminum SARA 313 toxic chemical notification and release reporting: Aluminum

Other Regulations:
OSHA: Hazardous by definition of Hazard Communication Standard (29 CFR 1910.1200). EINECS: This product is on the European Inventory of Existing Commercial Chemical Substances.

Other Classifications:

WHMIS (Canada): Not controlled under WHMIS (Canada).

DSCL (EEC):

HMIS (U.S.A.):

- **Health Hazard:** 1
- **Fire Hazard:** 0
- **Reactivity:** 0
- **Personal Protection:** B

National Fire Protection Association (U.S.A.):

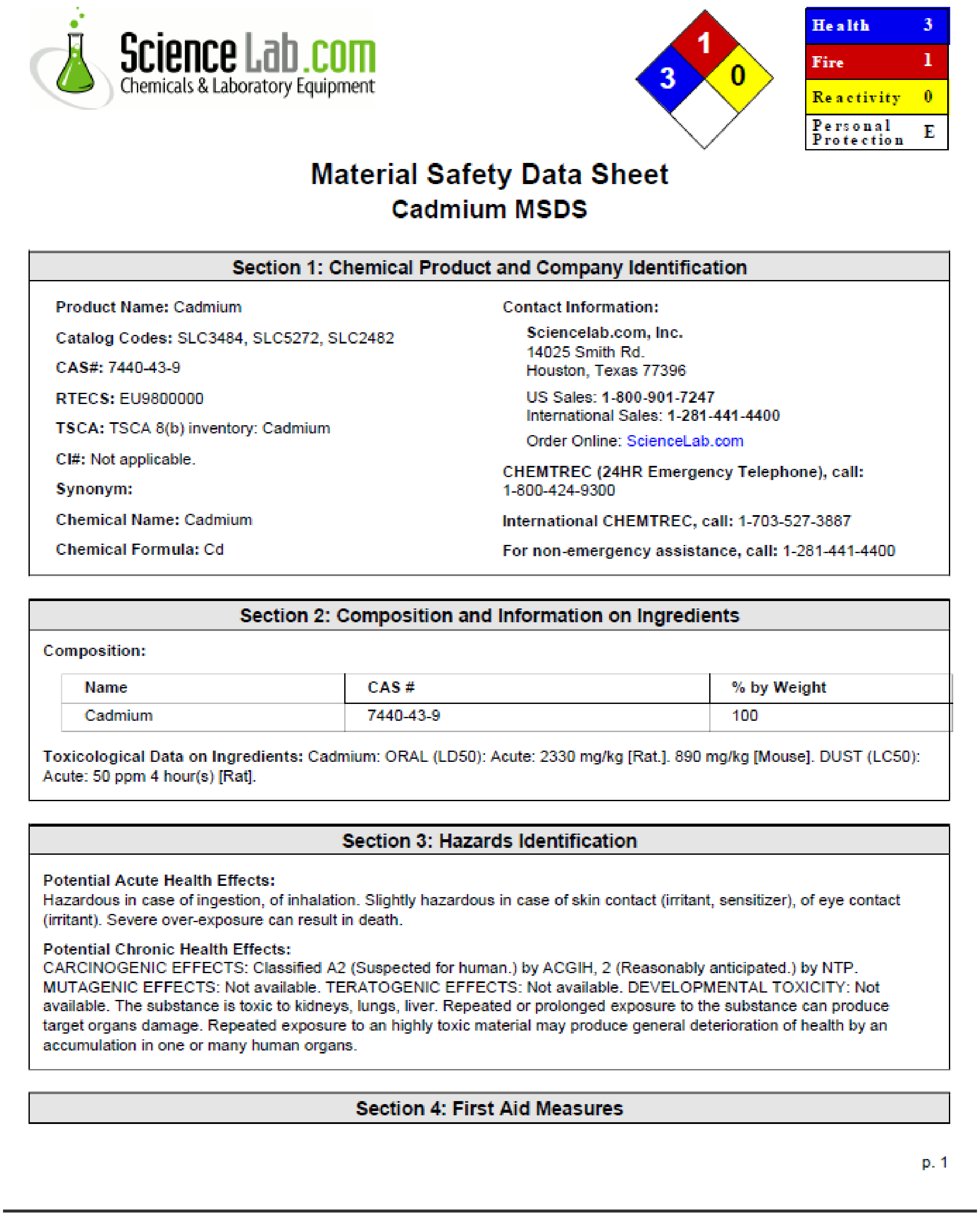
- **Health:** 1
- **Flammability:** 1
- **Reactivity:** 0
- **Specific hazard:**

Protective Equipment:
Gloves. Lab coat. Not applicable. Safety glasses.

Section 16: Other Information

References:

Cadmium



ScienceLab.com
Chemicals & Laboratory Equipment

Health	3
Fire	1
Reactivity	0
Personal Protection	E

Material Safety Data Sheet
Cadmium MSDS

Section 1: Chemical Product and Company Identification

Product Name: Cadmium

Catalog Codes: SLC3484, SLC5272, SLC2482

CAS#: 7440-43-9

RTECS: EU9800000

TSCA: TSCA 8(b) inventory: Cadmium

CI#: Not applicable.

Synonym:

Chemical Name: Cadmium

Chemical Formula: Cd

Contact Information:

Sciencelab.com, Inc.
14025 Smith Rd.
Houston, Texas 77396

US Sales: **1-800-901-7247**
International Sales: **1-281-441-4400**

Order Online: ScienceLab.com

CHEMTREC (24HR Emergency Telephone), call:
1-800-424-9300

International CHEMTREC, call: 1-703-527-3887

For non-emergency assistance, call: 1-281-441-4400

Section 2: Composition and Information on Ingredients

Composition:

Name	CAS #	% by Weight
Cadmium	7440-43-9	100

Toxicological Data on Ingredients: Cadmium: ORAL (LD50): Acute: 2330 mg/kg [Rat.]. 890 mg/kg [Mouse]. DUST (LC50): Acute: 50 ppm 4 hour(s) [Rat].

Section 3: Hazards Identification

Potential Acute Health Effects:
Hazardous in case of ingestion, of inhalation. Slightly hazardous in case of skin contact (irritant, sensitizer), of eye contact (irritant). Severe over-exposure can result in death.

Potential Chronic Health Effects:
CARCINOGENIC EFFECTS: Classified A2 (Suspected for human.) by ACGIH, 2 (Reasonably anticipated.) by NTP. MUTAGENIC EFFECTS: Not available. TERATOGENIC EFFECTS: Not available. DEVELOPMENTAL TOXICITY: Not available. The substance is toxic to kidneys, lungs, liver. Repeated or prolonged exposure to the substance can produce target organs damage. Repeated exposure to an highly toxic material may produce general deterioration of health by an accumulation in one or many human organs.

Section 4: First Aid Measures

p. 1

Eye Contact: No known effect on eye contact, rinse with water for a few minutes.

Skin Contact:
After contact with skin, wash immediately with plenty of water. Gently and thoroughly wash the contaminated skin with running water and non-abrasive soap. Be particularly careful to clean folds, crevices, creases and groin. Cover the irritated skin with an emollient. If irritation persists, seek medical attention. Wash contaminated clothing before reusing.

Serious Skin Contact: Not available.

Inhalation: Allow the victim to rest in a well ventilated area. Seek immediate medical attention.

Serious Inhalation:
Evacuate the victim to a safe area as soon as possible. Loosen tight clothing such as a collar, tie, belt or waistband. If breathing is difficult, administer oxygen. If the victim is not breathing, perform mouth-to-mouth resuscitation. WARNING: It may be hazardous to the person providing aid to give mouth-to-mouth resuscitation when the inhaled material is toxic, infectious or corrosive. Seek immediate medical attention.

Ingestion:
Do not induce vomiting. Examine the lips and mouth to ascertain whether the tissues are damaged, a possible indication that the toxic material was ingested; the absence of such signs, however, is not conclusive. Loosen tight clothing such as a collar, tie, belt or waistband. If the victim is not breathing, perform mouth-to-mouth resuscitation. Seek immediate medical attention.

Serious Ingestion: Not available.

Section 5: Fire and Explosion Data

Flammability of the Product: May be combustible at high temperature.

Auto-Ignition Temperature: 570°C (1058°F)

Flash Points: Not available.

Flammable Limits: Not available.

Products of Combustion: Some metallic oxides.

Fire Hazards in Presence of Various Substances:
Non-flammable in presence of open flames and sparks, of heat, of oxidizing materials, of reducing materials, of combustible materials, of moisture.

Explosion Hazards in Presence of Various Substances:
Risks of explosion of the product in presence of mechanical impact: Not available. Risks of explosion of the product in presence of static discharge: Not available.

Fire Fighting Media and Instructions:
SMALL FIRE: Use DRY chemical powder. LARGE FIRE: Use water spray, fog or foam. Do not use water jet.

Special Remarks on Fire Hazards:
Material in powder form, capable of creating a dust explosion. When heated to decomposition it emits toxic fumes.

Special Remarks on Explosion Hazards: Not available.

Section 6: Accidental Release Measures

Small Spill: Use appropriate tools to put the spilled solid in a convenient waste disposal container.

Large Spill:
Use a shovel to put the material into a convenient waste disposal container. Be careful that the product is not present at a concentration level above TLV. Check TLV on the MSDS and with local authorities.

Section 7: Handling and Storage

Precautions:
Keep locked up Keep away from heat. Keep away from sources of ignition. Empty containers pose a fire risk, evaporate the residue under a fume hood. Ground all equipment containing material. Do not ingest. Do not breathe dust. Wear suitable protective clothing In case of insufficient ventilation, wear suitable respiratory equipment If ingested, seek medical advice immediately and show the container or the label. Keep away from incompatibles such as oxidizing agents.

Storage:
Keep container dry. Keep in a cool place. Ground all equipment containing material. Keep container tightly closed. Keep in a cool, well-ventilated place. Highly toxic or infectious materials should be stored in a separate locked safety storage cabinet or room.

Section 8: Exposure Controls/Personal Protection

Engineering Controls:
Use process enclosures, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. If user operations generate dust, fume or mist, use ventilation to keep exposure to airborne contaminants below the exposure limit.

Personal Protection: Safety glasses. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Gloves.

Personal Protection in Case of a Large Spill:
Splash goggles. Full suit. Dust respirator. Boots. Gloves. A self contained breathing apparatus should be used to avoid inhalation of the product. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.

Exposure Limits:
TWA: 0.01 (ppm) Consult local authorities for acceptable exposure limits.

Section 9: Physical and Chemical Properties

Physical state and appearance: Solid. (Lustrous solid.)

Odor: Not available.

Taste: Not available.

Molecular Weight: 112.4 g/mole

Color: Silvery.

pH (1% soln/water): Not applicable.

Boiling Point: 765°C (1409°F)

Melting Point: 320.9°C (609.6°F)

Critical Temperature: Not available.

Specific Gravity: 8.64 (Water = 1)

Vapor Pressure: Not applicable.

Vapor Density: Not available.

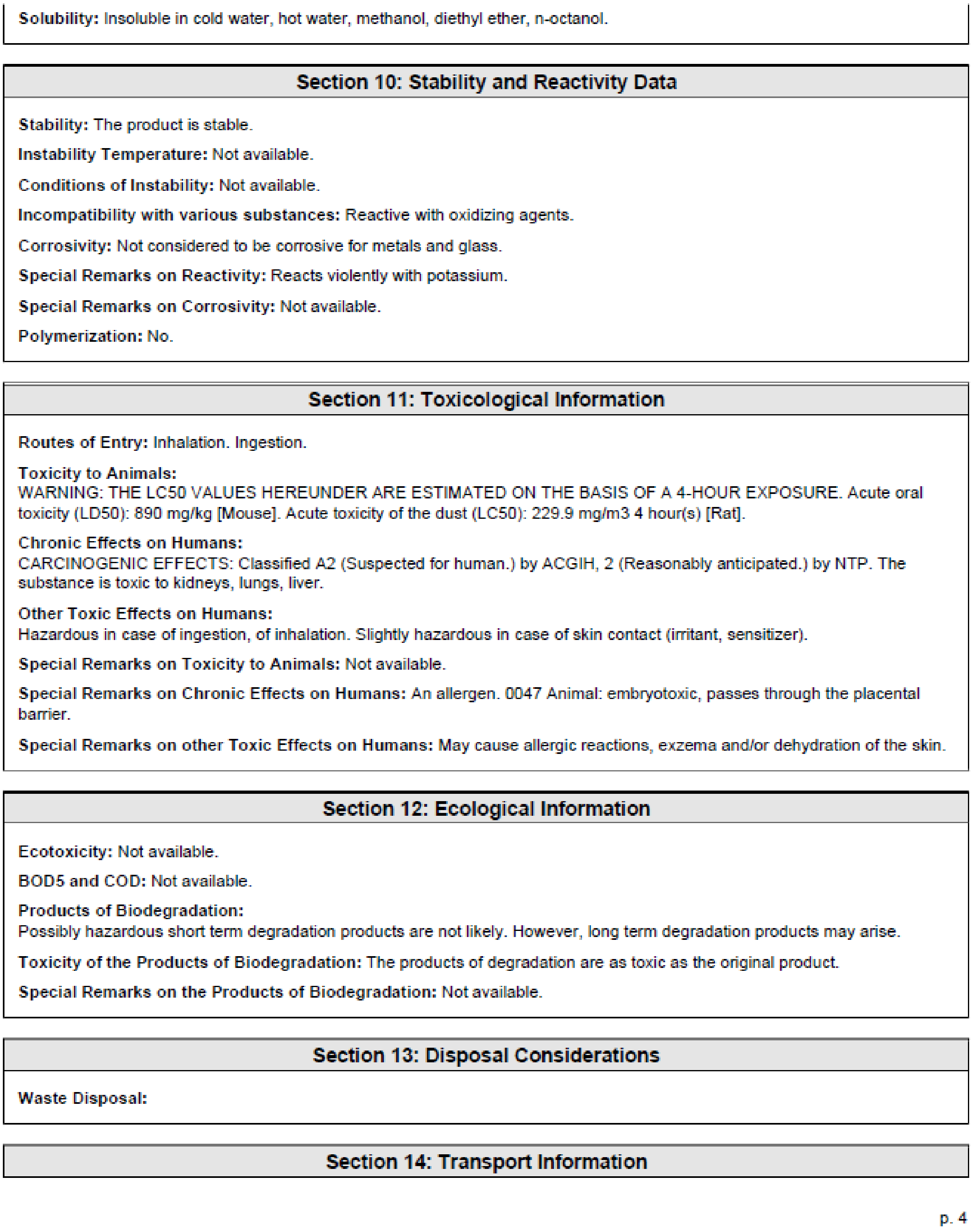
Volatility: Not available.

Odor Threshold: Not available.

Water/Oil Dist. Coeff.: Not available.

Ionicity (in Water): Not available.

Dispersion Properties: Not available.



Solubility: Insoluble in cold water, hot water, methanol, diethyl ether, n-octanol.

Section 10: Stability and Reactivity Data

Stability: The product is stable.

Instability Temperature: Not available.

Conditions of Instability: Not available.

Incompatibility with various substances: Reactive with oxidizing agents.

Corrosivity: Not considered to be corrosive for metals and glass.

Special Remarks on Reactivity: Reacts violently with potassium.

Special Remarks on Corrosivity: Not available.

Polymerization: No.

Section 11: Toxicological Information

Routes of Entry: Inhalation. Ingestion.

Toxicity to Animals:
WARNING: THE LC50 VALUES HEREUNDER ARE ESTIMATED ON THE BASIS OF A 4-HOUR EXPOSURE. Acute oral toxicity (LD50): 890 mg/kg [Mouse]. Acute toxicity of the dust (LC50): 229.9 mg/m3 4 hour(s) [Rat].

Chronic Effects on Humans:
CARCINOGENIC EFFECTS: Classified A2 (Suspected for human.) by ACGIH, 2 (Reasonably anticipated.) by NTP. The substance is toxic to kidneys, lungs, liver.

Other Toxic Effects on Humans:
Hazardous in case of ingestion, of inhalation. Slightly hazardous in case of skin contact (irritant, sensitizer).

Special Remarks on Toxicity to Animals: Not available.

Special Remarks on Chronic Effects on Humans: An allergen. 0047 Animal: embryotoxic, passes through the placental barrier.

Special Remarks on other Toxic Effects on Humans: May cause allergic reactions, exzema and/or dehydration of the skin.

Section 12: Ecological Information

Ecotoxicity: Not available.

BOD5 and COD: Not available.

Products of Biodegradation:
Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

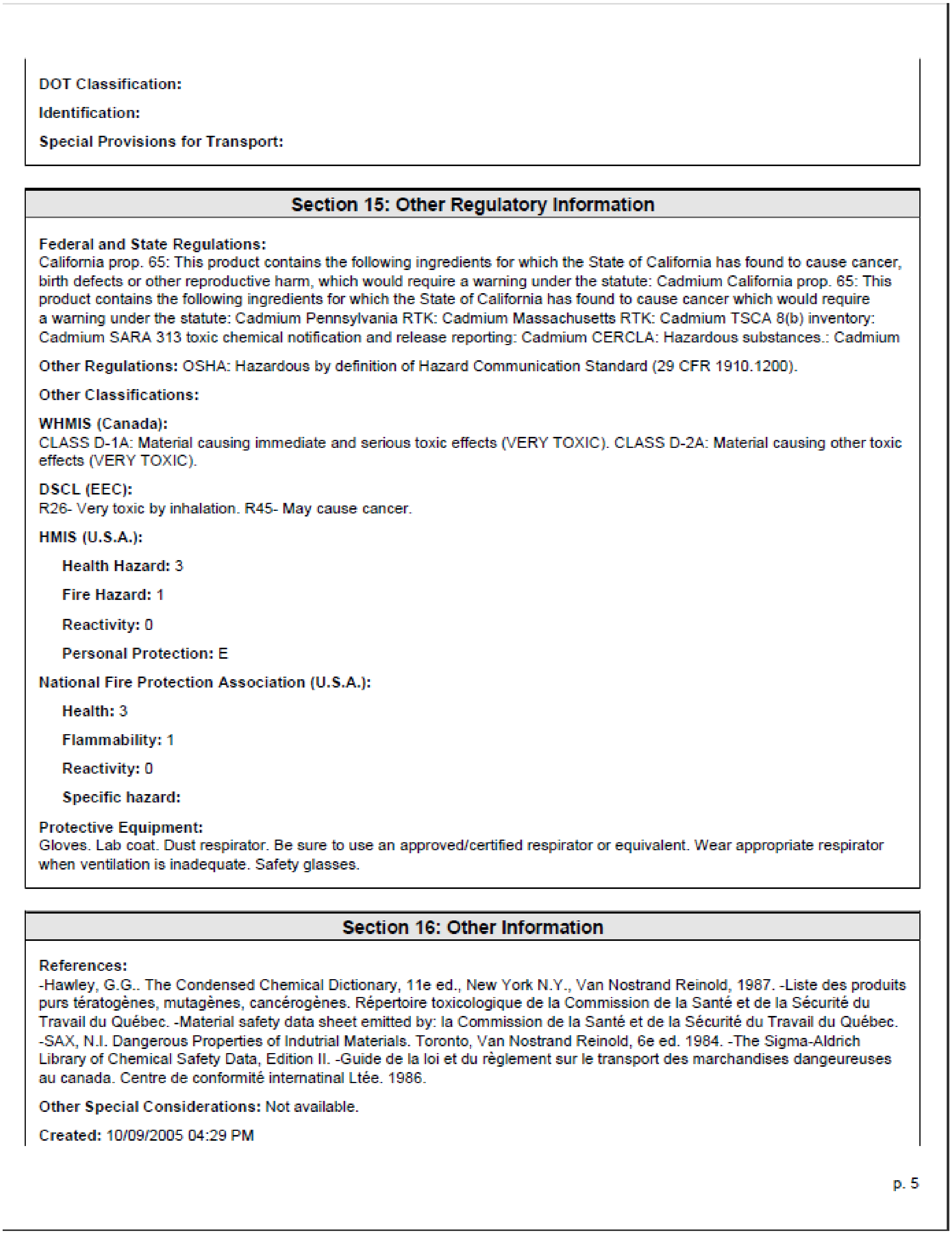
Toxicity of the Products of Biodegradation: The products of degradation are as toxic as the original product.

Special Remarks on the Products of Biodegradation: Not available.

Section 13: Disposal Considerations

Waste Disposal:

Section 14: Transport Information



DOT Classification:

Identification:

Special Provisions for Transport:

Section 15: Other Regulatory Information

Federal and State Regulations:
California prop. 65: This product contains the following ingredients for which the State of California has found to cause cancer, birth defects or other reproductive harm, which would require a warning under the statute: Cadmium California prop. 65: This product contains the following ingredients for which the State of California has found to cause cancer which would require a warning under the statute: Cadmium Pennsylvania RTK: Cadmium Massachusetts RTK: Cadmium TSCA 8(b) inventory: Cadmium SARA 313 toxic chemical notification and release reporting: Cadmium CERCLA: Hazardous substances.: Cadmium

Other Regulations: OSHA: Hazardous by definition of Hazard Communication Standard (29 CFR 1910.1200).

Other Classifications:

WHMIS (Canada):
CLASS D-1A: Material causing immediate and serious toxic effects (VERY TOXIC). CLASS D-2A: Material causing other toxic effects (VERY TOXIC).

DSCL (EEC):
R26- Very toxic by inhalation. R45- May cause cancer.

HMIS (U.S.A.):

Health Hazard: 3

Fire Hazard: 1

Reactivity: 0

Personal Protection: E

National Fire Protection Association (U.S.A.):

Health: 3

Flammability: 1

Reactivity: 0

Specific hazard:

Protective Equipment:
Gloves. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Wear appropriate respirator when ventilation is inadequate. Safety glasses.

Section 16: Other Information

References:
-Hawley, G.G.. The Condensed Chemical Dictionary, 11e ed., New York N.Y., Van Nostrand Reinold, 1987. -Liste des produits purs tératogènes, mutagènes, cancérogènes. Répertoire toxicologique de la Commission de la Santé et de la Sécurité du Travail du Québec. -Material safety data sheet emitted by: la Commission de la Santé et de la Sécurité du Travail du Québec. -SAX, N.I. Dangerous Properties of Indutrial Materials. Toronto, Van Nostrand Reinold, 6e ed. 1984. -The Sigma-Aldrich Library of Chemical Safety Data, Edition II. -Guide de la loi et du règlement sur le transport des marchandises dangeureuses au canada. Centre de conformité internatinal Ltée. 1986.

Other Special Considerations: Not available.

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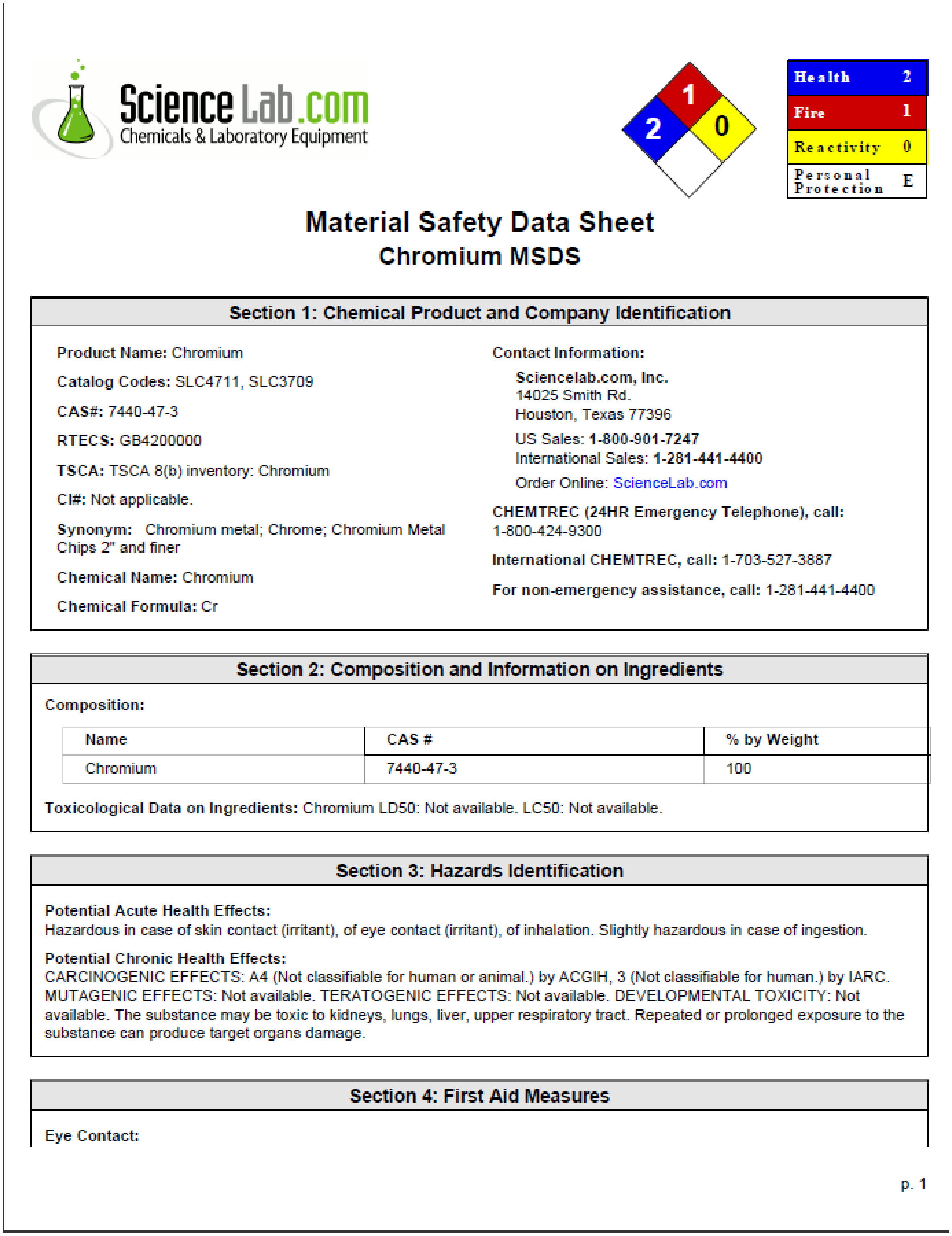


Health	2
Fire	1
Reactivity	0
Personal Protection	E

Material Safety Data Sheet
Chromium MSDS

Section 1: Chemical Product and Company Identification

Product Name: Chromium

Catalog Codes: SLC4711, SLC3709

CAS#: 7440-47-3

RTECS: GB4200000

TSCA: TSCA 8(b) inventory: Chromium

CI#: Not applicable.

Synonym: Chromium metal; Chrome; Chromium Metal Chips 2" and finer

Chemical Name: Chromium

Chemical Formula: Cr

Contact Information:

Sciencelab.com, Inc.
14025 Smith Rd.
Houston, Texas 77396

US Sales: **1-800-901-7247**
International Sales: **1-281-441-4400**

Order Online: ScienceLab.com

CHEMTREC (24HR Emergency Telephone), call:
1-800-424-9300

International CHEMTREC, call: 1-703-527-3887

For non-emergency assistance, call: 1-281-441-4400

Section 2: Composition and Information on Ingredients

Composition:

Name	CAS #	% by Weight
Chromium	7440-47-3	100

Toxicological Data on Ingredients: Chromium LD50: Not available. LC50: Not available.

Section 3: Hazards Identification

Potential Acute Health Effects:
Hazardous in case of skin contact (irritant), of eye contact (irritant), of inhalation. Slightly hazardous in case of ingestion.

Potential Chronic Health Effects:
CARCINOGENIC EFFECTS: A4 (Not classifiable for human or animal.) by ACGIH, 3 (Not classifiable for human.) by IARC. MUTAGENIC EFFECTS: Not available. TERATOGENIC EFFECTS: Not available. DEVELOPMENTAL TOXICITY: Not available. The substance may be toxic to kidneys, lungs, liver, upper respiratory tract. Repeated or prolonged exposure to the substance can produce target organs damage.

Section 4: First Aid Measures

Eye Contact:

Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Get medical attention.

Skin Contact:
In case of contact, immediately flush skin with plenty of water. Cover the irritated skin with an emollient. Remove contaminated clothing and shoes. Wash clothing before reuse. Thoroughly clean shoes before reuse. Get medical attention.

Serious Skin Contact:
Wash with a disinfectant soap and cover the contaminated skin with an anti-bacterial cream. Seek medical attention.

Inhalation:
If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention.

Serious Inhalation: Not available.

Ingestion:
Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Loosen tight clothing such as a collar, tie, belt or waistband. Get medical attention if symptoms appear.

Serious Ingestion: Not available.

Section 5: Fire and Explosion Data

Flammability of the Product: May be combustible at high temperature.

Auto-Ignition Temperature: 580°C (1076°F)

Flash Points: Not available.

Flammable Limits: Not available.

Products of Combustion: Some metallic oxides.

Fire Hazards in Presence of Various Substances:
Slightly flammable to flammable in presence of open flames and sparks, of heat. Non-flammable in presence of shocks.

Explosion Hazards in Presence of Various Substances:
Risks of explosion of the product in presence of mechanical impact: Not available. Risks of explosion of the product in presence of static discharge: Not available.

Fire Fighting Media and Instructions:
SMALL FIRE: Use DRY chemical powder. LARGE FIRE: Use water spray, fog or foam. Do not use water jet.

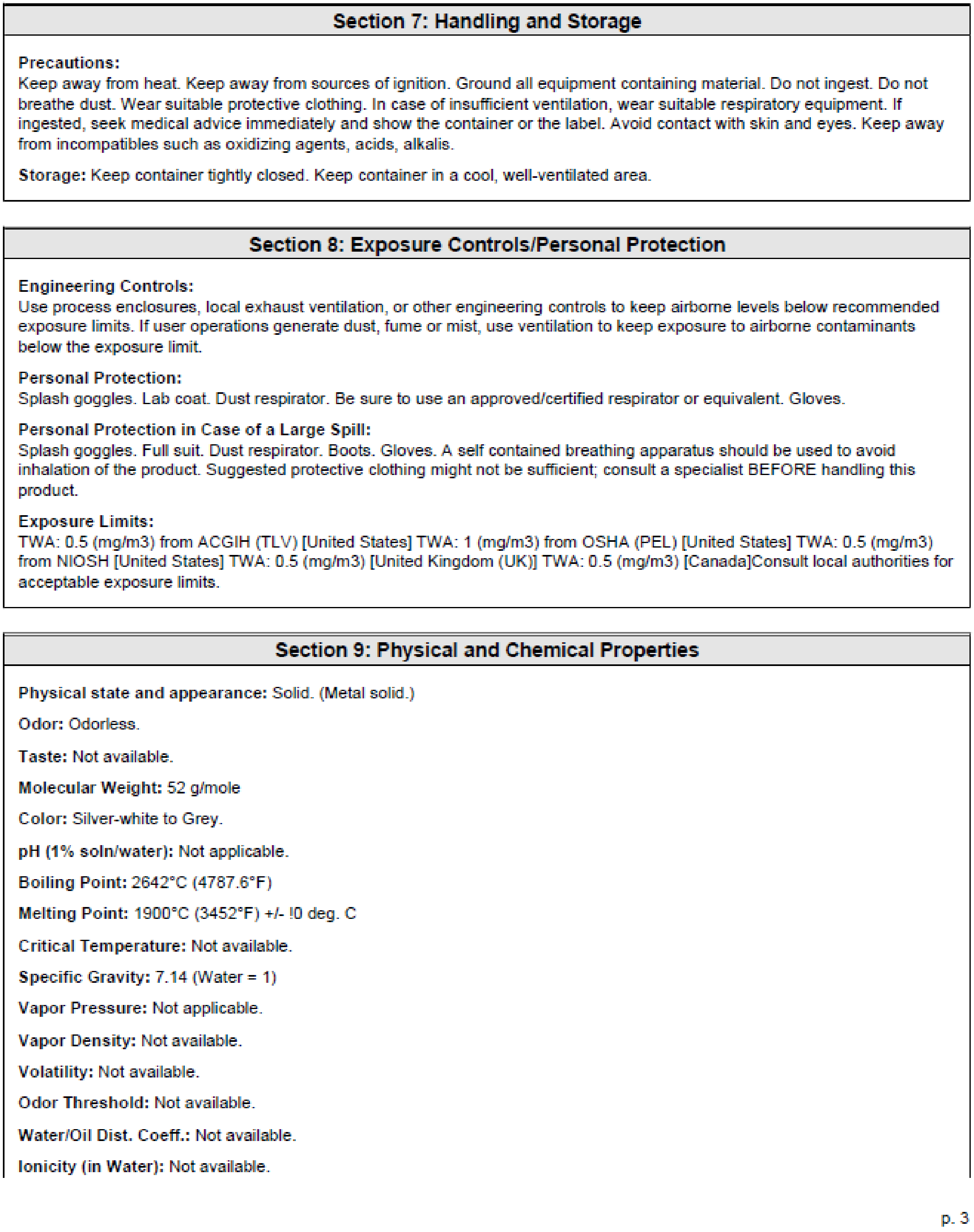
Special Remarks on Fire Hazards:
Moderate fire hazard when it is in the form of a dust (powder) and burns rapidly when heated in flame. Chromium is attacked vigorously by fused potassium chlorate producing vivid incandescence. Pyrophoric chromium unites with nitric oxide with incandescence. Incandescent reaction with nitrogen oxide or sulfur dioxide.

Special Remarks on Explosion Hazards:
Powdered Chromium metal +fused ammonium nitrate may react violently or explosively. Powdered Chromium will explode spontaneously in air.

Section 6: Accidental Release Measures

Small Spill:
Use appropriate tools to put the spilled solid in a convenient waste disposal container. Finish cleaning by spreading water on the contaminated surface and dispose of according to local and regional authority requirements.

Large Spill:
Use a shovel to put the material into a convenient waste disposal container. Finish cleaning by spreading water on the contaminated surface and allow to evacuate through the sanitary system. Be careful that the product is not present at a concentration level above TLV. Check TLV on the MSDS and with local authorities.



Section 7: Handling and Storage

Precautions:
Keep away from heat. Keep away from sources of ignition. Ground all equipment containing material. Do not ingest. Do not breathe dust. Wear suitable protective clothing. In case of insufficient ventilation, wear suitable respiratory equipment. If ingested, seek medical advice immediately and show the container or the label. Avoid contact with skin and eyes. Keep away from incompatibles such as oxidizing agents, acids, alkalis.

Storage: Keep container tightly closed. Keep container in a cool, well-ventilated area.

Section 8: Exposure Controls/Personal Protection

Engineering Controls:
Use process enclosures, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. If user operations generate dust, fume or mist, use ventilation to keep exposure to airborne contaminants below the exposure limit.

Personal Protection:
Splash goggles. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Gloves.

Personal Protection in Case of a Large Spill:
Splash goggles. Full suit. Dust respirator. Boots. Gloves. A self contained breathing apparatus should be used to avoid inhalation of the product. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.

Exposure Limits:
TWA: 0.5 (mg/m3) from ACGIH (TLV) [United States] TWA: 1 (mg/m3) from OSHA (PEL) [United States] TWA: 0.5 (mg/m3) from NIOSH [United States] TWA: 0.5 (mg/m3) [United Kingdom (UK)] TWA: 0.5 (mg/m3) [Canada]Consult local authorities for acceptable exposure limits.

Section 9: Physical and Chemical Properties

Physical state and appearance: Solid. (Metal solid.)

Odor: Odorless.

Taste: Not available.

Molecular Weight: 52 g/mole

Color: Silver-white to Grey.

pH (1% soln/water): Not applicable.

Boiling Point: 2642°C (4787.6°F)

Melting Point: 1900°C (3452°F) +/- !0 deg. C

Critical Temperature: Not available.

Specific Gravity: 7.14 (Water = 1)

Vapor Pressure: Not applicable.

Vapor Density: Not available.

Volatility: Not available.

Odor Threshold: Not available.

Water/Oil Dist. Coeff.: Not available.

Ionicity (in Water): Not available.

Dispersion Properties: Not available.

Solubility:
Insoluble in cold water, hot water. Soluble in acids (except Nitric), and strong alkalies.

Section 10: Stability and Reactivity Data

Stability: The product is stable.

Instability Temperature: Not available.

Conditions of Instability: Excess heat, incompatible materials

Incompatibility with various substances: Reactive with oxidizing agents, acids, alkalis.

Corrosivity: Not available.

Special Remarks on Reactivity:
Incompatible with molten Lithium at 180 deg. C, hydrogen peroxide, hydrochloric acid, sulfuric acid, most caustic alkalies and alkali carbonates, potassium chlorate, sulfur dioxide, nitrogen oxide, bromine pentafluoride. It may react violently or ignite with bromine pentafluoride. Chromium is rapidly attacked by fused sodium hydroxide + potassium nitrate. Potentially hazardous incompatibility with strong oxidizers.

Special Remarks on Corrosivity: Not available.

Polymerization: Will not occur.

Section 11: Toxicological Information

Routes of Entry: Inhalation. Ingestion.

Toxicity to Animals:
LD50: Not available. LC50: Not available.

Chronic Effects on Humans:
CARCINOGENIC EFFECTS: A4 (Not classifiable for human or animal.) by ACGIH, 3 (Not classifiable for human.) by IARC. May cause damage to the following organs: kidneys, lungs, liver, upper respiratory tract.

Other Toxic Effects on Humans:
Hazardous in case of skin contact (irritant), of inhalation. Slightly hazardous in case of ingestion.

Special Remarks on Toxicity to Animals: Not available.

Special Remarks on Chronic Effects on Humans:
May cause cancer based on animal data. There is no evidence that exposure to trivalent chromium causes cancer in man.

Special Remarks on other Toxic Effects on Humans:
Acute Potential Health Effects: May cause skin irritation. Eyes: May cause mechanical eye irritation. Inhalation: May cause irritation of the respiratory tract and mucous membranes of the respiratory tract. Ingestion: May cause gastrointestinal tract irritation with nausea, vomiting, diarrhea. Chronic Potential Health Effects: Inhalation: The effects of chronic exposure include irritation , sneezing, reddness of the throat, bronchospasm, asthma, cough, polyps, chronic inflammation, emphysema, chronic bronchitis, pharyngitis, bronchopneumonia, pneumoconoisis. Effects on the nose from chronic chromium exposure include irritation, ulceration, and perforation of the nasal septum. Inflammation and ulceration of the larynx may also occur. Ingestion or Inhalation: Chronic exposure may cause liver and kidney damage.

Section 12: Ecological Information

Ecotoxicity: Not available.

BOD5 and COD: Not available.

Products of Biodegradation:
Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

Toxicity of the Products of Biodegradation: The product itself and its products of degradation are not toxic.

Special Remarks on the Products of Biodegradation: Not available.

Section 13: Disposal Considerations

Waste Disposal:
Waste must be disposed of in accordance with federal, state and local environmental control regulations.

Section 14: Transport Information

DOT Classification: Not a DOT controlled material (United States).

Identification: Not applicable.

Special Provisions for Transport: Not applicable.

Section 15: Other Regulatory Information

Federal and State Regulations:
Connecticut hazardous material survey.: Chromium Illinois toxic substances disclosure to employee act: Chromium Illinois chemical safety act: Chromium New York release reporting list: Chromium Rhode Island RTK hazardous substances: Chromium Pennsylvania RTK: Chromium Minnesota: Chromium Michigan critical material: Chromium Massachusetts RTK: Chromium Massachusetts spill list: Chromium New Jersey: Chromium New Jersey spill list: Chromium Louisiana spill reporting: Chromium California Director's List of Hazardous Substances: Chromium TSCA 8(b) inventory: Chromium SARA 313 toxic chemical notification and release reporting: Chromium CERCLA: Hazardous substances.: Chromium: 5000 lbs. (2268 kg)

Other Regulations:
OSHA: Hazardous by definition of Hazard Communication Standard (29 CFR 1910.1200). EINECS: This product is on the European Inventory of Existing Commercial Chemical Substances.

Other Classifications:

WHMIS (Canada): Not controlled under WHMIS (Canada).

DSCL (EEC):
R40- Limited evidence of carcinogenic effect S36/37/39- Wear suitable protective clothing, gloves and eye/face protection. S45- In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible).

HMIS (U.S.A.):

Health Hazard: 2

Fire Hazard: 1

Reactivity: 0

Personal Protection: E

National Fire Protection Association (U.S.A.):

Health: 2

Flammability: 1

Reactivity: 0

Specific hazard:

Protective Equipment:
Gloves. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Splash goggles.

Section 16: Other Information

References: Not available.

Other Special Considerations: Not available.

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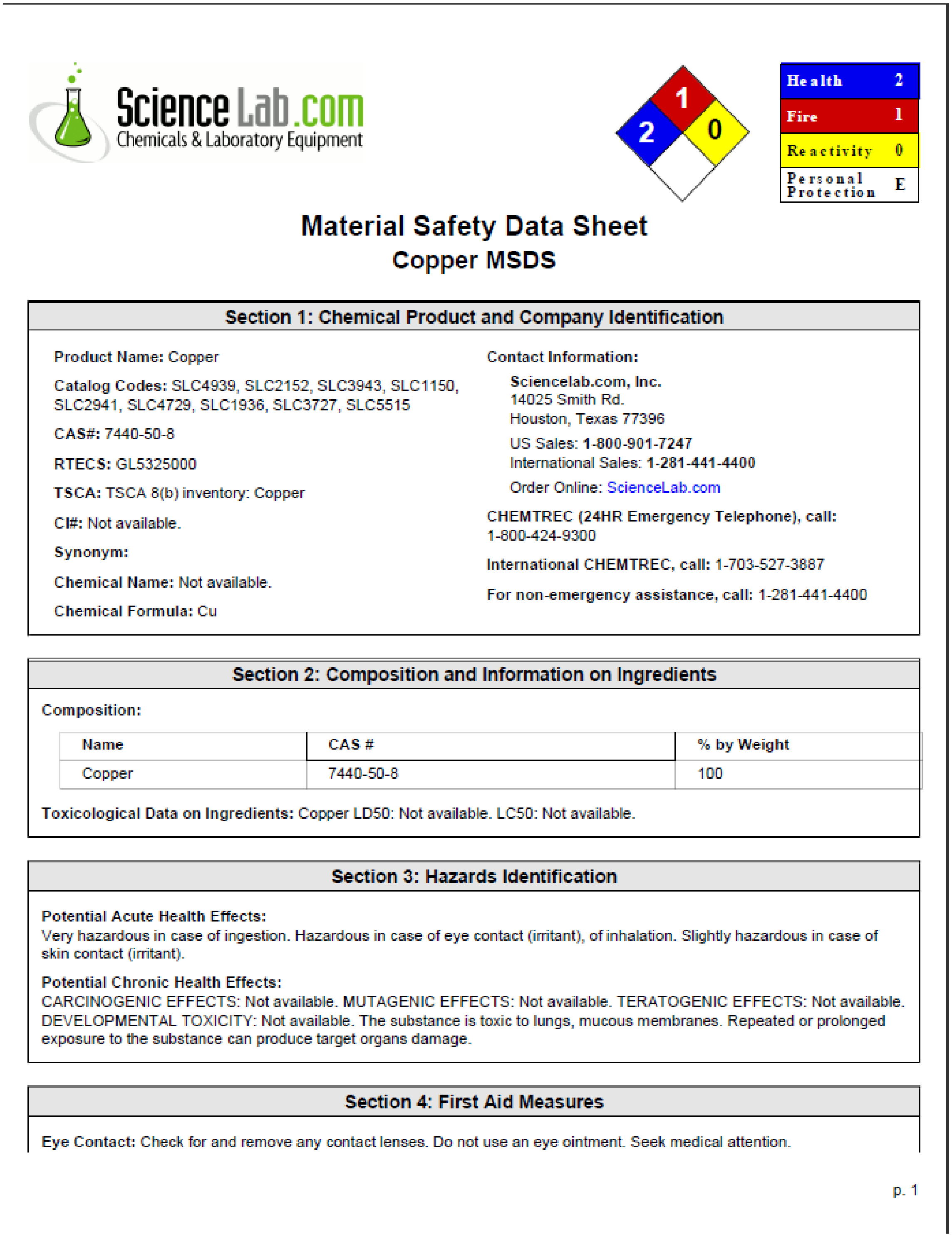
Copper



ScienceLab.com
Chemicals & Laboratory Equipment

Health	2
Fire	1
Reactivity	0
Personal Protection	E

Material Safety Data Sheet
Copper MSDS

Section 1: Chemical Product and Company Identification

Product Name: Copper

Catalog Codes: SLC4939, SLC2152, SLC3943, SLC1150, SLC2941, SLC4729, SLC1936, SLC3727, SLC5515

CAS#: 7440-50-8

RTECS: GL5325000

TSCA: TSCA 8(b) inventory: Copper

CI#: Not available.

Synonym:

Chemical Name: Not available.

Chemical Formula: Cu

Contact Information:

Sciencelab.com, Inc.
14025 Smith Rd.
Houston, Texas 77396

US Sales: **1-800-901-7247**
International Sales: **1-281-441-4400**

Order Online: ScienceLab.com

CHEMTREC (24HR Emergency Telephone), call:
1-800-424-9300

International CHEMTREC, call: 1-703-527-3887

For non-emergency assistance, call: 1-281-441-4400

Section 2: Composition and Information on Ingredients

Composition:

Name	CAS #	% by Weight
Copper	7440-50-8	100

Toxicological Data on Ingredients: Copper LD50: Not available. LC50: Not available.

Section 3: Hazards Identification

Potential Acute Health Effects:
Very hazardous in case of ingestion. Hazardous in case of eye contact (irritant), of inhalation. Slightly hazardous in case of skin contact (irritant).

Potential Chronic Health Effects:
CARCINOGENIC EFFECTS: Not available. MUTAGENIC EFFECTS: Not available. TERATOGENIC EFFECTS: Not available. DEVELOPMENTAL TOXICITY: Not available. The substance is toxic to lungs, mucous membranes. Repeated or prolonged exposure to the substance can produce target organs damage.

Section 4: First Aid Measures

Eye Contact: Check for and remove any contact lenses. Do not use an eye ointment. Seek medical attention.

Skin Contact:
After contact with skin, wash immediately with plenty of water. Gently and thoroughly wash the contaminated skin with running water and non-abrasive soap. Be particularly careful to clean folds, crevices, creases and groin. Cover the irritated skin with an emollient. If irritation persists, seek medical attention. Wash contaminated clothing before reusing.

Serious Skin Contact: Not available.

Inhalation: Allow the victim to rest in a well ventilated area. Seek immediate medical attention.

Serious Inhalation: Not available.

Ingestion:
Do not induce vomiting. Loosen tight clothing such as a collar, tie, belt or waistband. If the victim is not breathing, perform mouth-to-mouth resuscitation. Seek immediate medical attention.

Serious Ingestion: Not available.

Section 5: Fire and Explosion Data

Flammability of the Product: May be combustible at high temperature.

Auto-Ignition Temperature: Not available.

Flash Points: Not available.

Flammable Limits: Not available.

Products of Combustion: Some metallic oxides.

Fire Hazards in Presence of Various Substances: Not available.

Explosion Hazards in Presence of Various Substances:
Risks of explosion of the product in presence of mechanical impact: Not available. Risks of explosion of the product in presence of static discharge: Not available.

Fire Fighting Media and Instructions:
SMALL FIRE: Use DRY chemical powder. LARGE FIRE: Use water spray, fog or foam. Do not use water jet.

Special Remarks on Fire Hazards: Not available.

Special Remarks on Explosion Hazards: Not available.

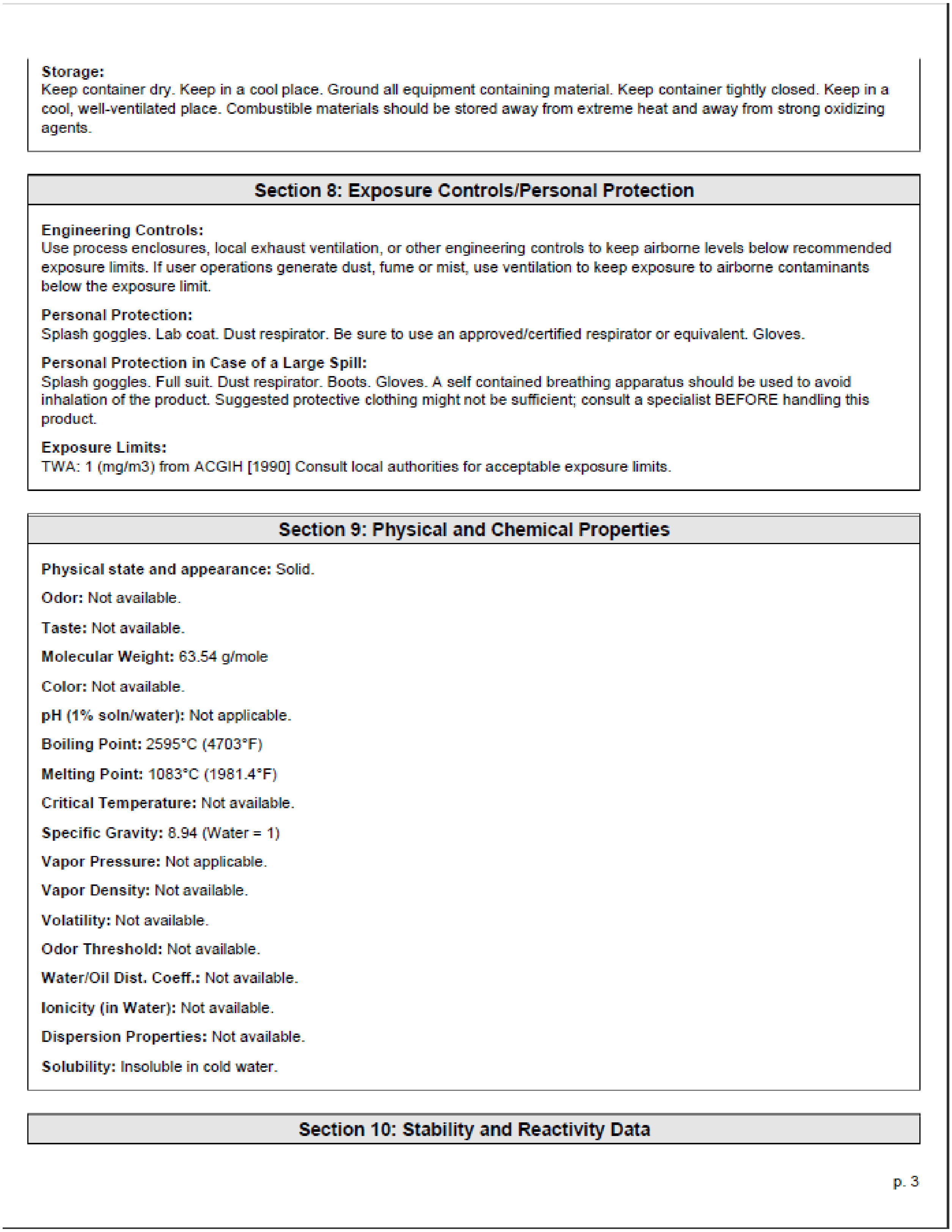
Section 6: Accidental Release Measures

Small Spill:
Use appropriate tools to put the spilled solid in a convenient waste disposal container. Finish cleaning by spreading water on the contaminated surface and dispose of according to local and regional authority requirements.

Large Spill:
Use a shovel to put the material into a convenient waste disposal container. Finish cleaning by spreading water on the contaminated surface and allow to evacuate through the sanitary system. Be careful that the product is not present at a concentration level above TLV. Check TLV on the MSDS and with local authorities.

Section 7: Handling and Storage

Precautions:
Keep away from heat. Keep away from sources of ignition. Empty containers pose a fire risk, evaporate the residue under a fume hood. Ground all equipment containing material. Do not breathe dust. Avoid contact with eyes Wear suitable protective clothing In case of insufficient ventilation, wear suitable respiratory equipment If you feel unwell, seek medical attention and show the label when possible.



Storage:
Keep container dry. Keep in a cool place. Ground all equipment containing material. Keep container tightly closed. Keep in a cool, well-ventilated place. Combustible materials should be stored away from extreme heat and away from strong oxidizing agents.

Section 8: Exposure Controls/Personal Protection

Engineering Controls:
Use process enclosures, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. If user operations generate dust, fume or mist, use ventilation to keep exposure to airborne contaminants below the exposure limit.

Personal Protection:
Splash goggles. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Gloves.

Personal Protection in Case of a Large Spill:
Splash goggles. Full suit. Dust respirator. Boots. Gloves. A self contained breathing apparatus should be used to avoid inhalation of the product. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.

Exposure Limits:
TWA: 1 (mg/m3) from ACGIH [1990] Consult local authorities for acceptable exposure limits.

Section 9: Physical and Chemical Properties

Physical state and appearance: Solid.

Odor: Not available.

Taste: Not available.

Molecular Weight: 63.54 g/mole

Color: Not available.

pH (1% soln/water): Not applicable.

Boiling Point: 2595°C (4703°F)

Melting Point: 1083°C (1981.4°F)

Critical Temperature: Not available.

Specific Gravity: 8.94 (Water = 1)

Vapor Pressure: Not applicable.

Vapor Density: Not available.

Volatility: Not available.

Odor Threshold: Not available.

Water/Oil Dist. Coeff.: Not available.

Ionicity (in Water): Not available.

Dispersion Properties: Not available.

Solubility: Insoluble in cold water.

Section 10: Stability and Reactivity Data

Stability: The product is stable.

Instability Temperature: Not available.

Conditions of Instability: Not available.

Incompatibility with various substances: Not available.

Corrosivity: Non-corrosive in presence of glass.

Special Remarks on Reactivity: Not available.

Special Remarks on Corrosivity: Not available.

Polymerization: No.

Section 11: Toxicological Information

Routes of Entry: Absorbed through skin. Eye contact. Inhalation. Ingestion.

Toxicity to Animals:
LD50: Not available. LC50: Not available.

Chronic Effects on Humans: The substance is toxic to lungs, mucous membranes.

Other Toxic Effects on Humans:
Very hazardous in case of ingestion. Hazardous in case of inhalation. Slightly hazardous in case of skin contact (irritant).

Special Remarks on Toxicity to Animals: Not available.

Special Remarks on Chronic Effects on Humans: Human: passes through the placenta, excreted in maternal milk.

Special Remarks on other Toxic Effects on Humans: Not available.

Section 12: Ecological Information

Ecotoxicity: Not available.

BOD5 and COD: Not available.

Products of Biodegradation:
Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

Toxicity of the Products of Biodegradation: The products of degradation are as toxic as the original product.

Special Remarks on the Products of Biodegradation: Not available.

Section 13: Disposal Considerations

Waste Disposal:

Section 14: Transport Information

DOT Classification: Not a DOT controlled material (United States).

Identification: Not applicable.

Special Provisions for Transport: Marine Pollutant

Section 15: Other Regulatory Information

Federal and State Regulations:
Pennsylvania RTK: Copper Massachusetts RTK: Copper TSCA 8(b) inventory: Copper CERCLA: Hazardous substances.: Copper

Other Regulations: OSHA: Hazardous by definition of Hazard Communication Standard (29 CFR 1910.1200).

Other Classifications:

WHMIS (Canada): CLASS D-2A: Material causing other toxic effects (VERY TOXIC).

DSCL (EEC): R36- Irritating to eyes.

HMIS (U.S.A.):

Health Hazard: 2

Fire Hazard: 1

Reactivity: 0

Personal Protection: E

National Fire Protection Association (U.S.A.):

Health: 2

Flammability: 1

Reactivity: 0

Specific hazard:

Protective Equipment:
Gloves. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Wear appropriate respirator when ventilation is inadequate. Splash goggles.

Section 16: Other Information

References: Not available.

Other Special Considerations: Not available.

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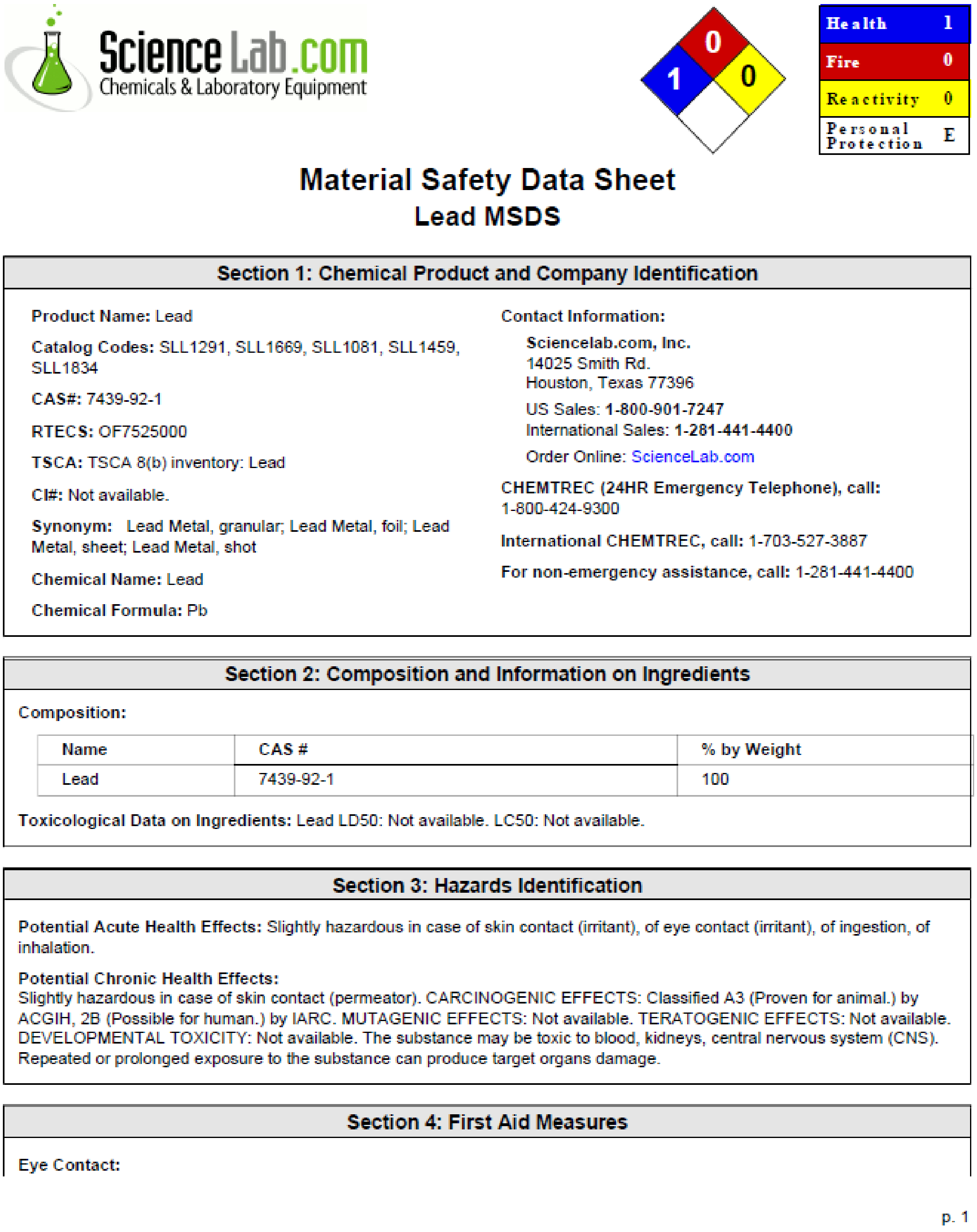

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Chemicals & Laboratory Equipment

Health	1
Fire	0
Reactivity	0
Personal Protection	E

Material Safety Data Sheet

Lead MSDS

Section 1: Chemical Product and Company Identification

Product Name: Lead

Catalog Codes: SLL1291, SLL1669, SLL1081, SLL1459, SLL1834

CAS#: 7439-92-1

RTECS: OF7525000

TSCA: TSCA 8(b) inventory: Lead

CI#: Not available.

Synonym: Lead Metal, granular; Lead Metal, foil; Lead Metal, sheet; Lead Metal, shot

Chemical Name: Lead

Chemical Formula: Pb

Contact Information:

Sciencelab.com, Inc.
14025 Smith Rd.
Houston, Texas 77396

US Sales: **1-800-901-7247**
International Sales: **1-281-441-4400**

Order Online: ScienceLab.com

CHEMTREC (24HR Emergency Telephone), call: 1-800-424-9300

International CHEMTREC, call: 1-703-527-3887

For non-emergency assistance, call: 1-281-441-4400

Section 2: Composition and Information on Ingredients

Composition:

Name	CAS #	% by Weight
Lead	7439-92-1	100

Toxicological Data on Ingredients: Lead LD50: Not available. LC50: Not available.

Section 3: Hazards Identification

Potential Acute Health Effects: Slightly hazardous in case of skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation.

Potential Chronic Health Effects:
Slightly hazardous in case of skin contact (permeator). CARCINOGENIC EFFECTS: Classified A3 (Proven for animal.) by ACGIH, 2B (Possible for human.) by IARC. MUTAGENIC EFFECTS: Not available. TERATOGENIC EFFECTS: Not available. DEVELOPMENTAL TOXICITY: Not available. The substance may be toxic to blood, kidneys, central nervous system (CNS). Repeated or prolonged exposure to the substance can produce target organs damage.

Section 4: First Aid Measures

Eye Contact:

Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Get medical attention if irritation occurs.

Skin Contact: Wash with soap and water. Cover the irritated skin with an emollient. Get medical attention if irritation develops.

Serious Skin Contact: Not available.

Inhalation:
If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention.

Serious Inhalation: Not available.

Ingestion:
Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. If large quantities of this material are swallowed, call a physician immediately. Loosen tight clothing such as a collar, tie, belt or waistband.

Serious Ingestion: Not available.

Section 5: Fire and Explosion Data

Flammability of the Product: May be combustible at high temperature.

Auto-Ignition Temperature: Not available.

Flash Points: Not available.

Flammable Limits: Not available.

Products of Combustion: Some metallic oxides.

Fire Hazards in Presence of Various Substances: Non-flammable in presence of open flames and sparks, of shocks, of heat.

Explosion Hazards in Presence of Various Substances:
Risks of explosion of the product in presence of mechanical impact: Not available. Risks of explosion of the product in presence of static discharge: Not available.

Fire Fighting Media and Instructions:
SMALL FIRE: Use DRY chemical powder. LARGE FIRE: Use water spray, fog or foam. Do not use water jet.

Special Remarks on Fire Hazards: When heated to decomposition it emits highly toxic fumes of lead.

Special Remarks on Explosion Hazards: Not available.

Section 6: Accidental Release Measures

Small Spill:
Use appropriate tools to put the spilled solid in a convenient waste disposal container. Finish cleaning by spreading water on the contaminated surface and dispose of according to local and regional authority requirements.

Large Spill:
Use a shovel to put the material into a convenient waste disposal container. Finish cleaning by spreading water on the contaminated surface and allow to evacuate through the sanitary system. Be careful that the product is not present at a concentration level above TLV. Check TLV on the MSDS and with local authorities.

Section 7: Handling and Storage

Precautions:
Keep locked up.. Keep away from heat. Keep away from sources of ignition. Empty containers pose a fire risk, evaporate the residue under a fume hood. Ground all equipment containing material. Do not ingest. Do not breathe dust. Wear suitable

protective clothing. If ingested, seek medical advice immediately and show the container or the label. Keep away from incompatibles such as oxidizing agents.

Storage: Keep container tightly closed. Keep container in a cool, well-ventilated area.

Section 8: Exposure Controls/Personal Protection

Engineering Controls:
Use process enclosures, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. If user operations generate dust, fume or mist, use ventilation to keep exposure to airborne contaminants below the exposure limit.

Personal Protection: Safety glasses. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Gloves.

Personal Protection in Case of a Large Spill:
Splash goggles. Full suit. Dust respirator. Boots. Gloves. A self contained breathing apparatus should be used to avoid inhalation of the product. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.

Exposure Limits:
TWA: 0.05 (mg/m3) from ACGIH (TLV) [United States] TWA: 0.05 (mg/m3) from OSHA (PEL) [United States] TWA: 0.03 (mg/m3) from NIOSH [United States] TWA: 0.05 (mg/m3) [Canada]Consult local authorities for acceptable exposure limits.

Section 9: Physical and Chemical Properties

Physical state and appearance: Solid. (Metal solid.)

Odor: Not available.

Taste: Not available.

Molecular Weight: 207.21 g/mole

Color: Bluish-white. Silvery. Gray

pH (1% soln/water): Not applicable.

Boiling Point: 1740°C (3164°F)

Melting Point: 327.43°C (621.4°F)

Critical Temperature: Not available.

Specific Gravity: 11.3 (Water = 1)

Vapor Pressure: Not applicable.

Vapor Density: Not available.

Volatility: Not available.

Odor Threshold: Not available.

Water/Oil Dist. Coeff.: Not available.

Ionicity (in Water): Not available.

Dispersion Properties: Not available.

Solubility: Insoluble in cold water.

Section 10: Stability and Reactivity Data

Stability: The product is stable.

Instability Temperature: Not available.

Conditions of Instability: Incompatible materials, excess heat

Incompatibility with various substances: Reactive with oxidizing agents.

Corrosivity: Non-corrosive in presence of glass.

Special Remarks on Reactivity:
Can react vigorously with oxidizing materials. Incompatible with sodium carbide, chlorine trifluoride, trioxane + hydrogen peroxide, ammonium nitrate, sodium azide, disodium acetylide, sodium acetylide, hot concentrated nitric acid, hot concentrated hydrochloric acid, hot concentrated sulfuric acid, zirconium.

Special Remarks on Corrosivity: Not available.

Polymerization: Will not occur.

Section 11: Toxicological Information

Routes of Entry: Absorbed through skin. Inhalation. Ingestion.

Toxicity to Animals:
LD50: Not available. LC50: Not available.

Chronic Effects on Humans:
CARCINOGENIC EFFECTS: Classified A3 (Proven for animal.) by ACGIH, 2B (Possible for human.) by IARC. May cause damage to the following organs: blood, kidneys, central nervous system (CNS).

Other Toxic Effects on Humans: Slightly hazardous in case of skin contact (irritant), of ingestion, of inhalation.

Special Remarks on Toxicity to Animals: Not available.

Special Remarks on Chronic Effects on Humans: Not available.

Special Remarks on other Toxic Effects on Humans:
Acute Potential: Skin: Lead metal granules or dust: May cause skin irritation by mechanical action. Lead metal foil, shot or sheets: Not likely to cause skin irritation Eyes: Lead metal granules or dust: Can irritate eyes by mechanical action. Lead metal foil, shot or sheets: No hazard. Will not cause eye irritation. Inhalation: In an industrial setting, exposure to lead mainly occurs from inhalation of dust or fumes. Lead dust or fumes: Can irritate the upper respiratory tract (nose, throat) as well as the bronchi and lungsby mechanical action. Lead dust can be absorbed through the respiratory system. However, inhaled lead does not accumulate in the lungs. All of an inhaled dose is eventually abssorbed or transferred to the gastrointestinal tract. Inhalation effects of exposure to fumes or dust of inorganic lead may not develop quickly. Symptoms may include metallic taste, chest pain, decreased physical fitness, fatigue, sleep disturbance, headache, irritability, reduces memory, mood and personality changes, aching bones and muscles, constipation, abdominal pains, decreasing appetite. Inhalation of large amounts may lead to ataxia, deliriuim, convulsions/seizures, coma, and death. Lead metal foil, shot, or sheets: Not an inhalation hazard unless metal is heated. If metal is heated, fumes will be released. Inhalation of these fumes may cause "fume metal fever", which is characterized by flu-like symptoms. Symptoms may include metallic taste, fever, nausea, vomiting, chills, cough, weakness, chest pain, generalized muscle pain/aches, and increased white blood cell count. Ingestion: Lead metal granules or dust: The symptoms of lead poisoning include abdominal pain or cramps (lead cholic), spasms, nausea, vomiting, headache, muscle weakness, hallucinations, distorted perceptions, "lead line" on the gums, metallic taste, loss of appetite, insomnia, dizziness and other symptoms similar to that of inhalation. Acute poisoning may result in high lead levels in the blood and urine, shock, coma and death in extreme cases. Lead metal foil, shot or sheets: Not an ingestion hazard for usual industrial handling.

Section 12: Ecological Information

Ecotoxicity: Not available.

BOD5 and COD: Not available.

Products of Biodegradation:
Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

Toxicity of the Products of Biodegradation: The products of degradation are less toxic than the product itself.

Special Remarks on the Products of Biodegradation: Not available.

Section 13: Disposal Considerations

Waste Disposal:
Waste must be disposed of in accordance with federal, state and local environmental control regulations.

Section 14: Transport Information

DOT Classification: Not a DOT controlled material (United States).

Identification: Not applicable.

Special Provisions for Transport: Not applicable.

Section 15: Other Regulatory Information

Federal and State Regulations:
California prop. 65: This product contains the following ingredients for which the State of California has found to cause cancer, birth defects or other reproductive harm, which would require a warning under the statute: Lead California prop. 65: This product contains the following ingredients for which the State of California has found to cause reproductive harm (female) which would require a warning under the statute: Lead California prop. 65: This product contains the following ingredients for which the State of California has found to cause reproductive harm (male) which would require a warning under the statute: Lead California prop. 65 (no significant risk level): Lead: 0.0005 mg/day (value) California prop. 65: This product contains the following ingredients for which the State of California has found to cause birth defects which would require a warning under the statute: Lead California prop. 65: This product contains the following ingredients for which the State of California has found to cause cancer which would require a warning under the statute: Lead Connecticut hazardous material survey.: Lead Illinois toxic substances disclosure to employee act: Lead Illinois chemical safety act: Lead New York release reporting list: Lead Rhode Island RTK hazardous substances: Lead Pennsylvania RTK: Lead

Other Regulations:
OSHA: Hazardous by definition of Hazard Communication Standard (29 CFR 1910.1200). EINECS: This product is on the European Inventory of Existing Commercial Chemical Substances.

Other Classifications:

WHMIS (Canada): CLASS D-2A: Material causing other toxic effects (VERY TOXIC).

DSCL (EEC):
R20/22- Harmful by inhalation and if swallowed. R33- Danger of cumulative effects. R61- May cause harm to the unborn child. R62- Possible risk of impaired fertility. S36/37- Wear suitable protective clothing and gloves. S44- If you feel unwell, seek medical advice (show the label when possible). S53- Avoid exposure - obtain special instructions before use.

HMIS (U.S.A.):

Health Hazard: 1

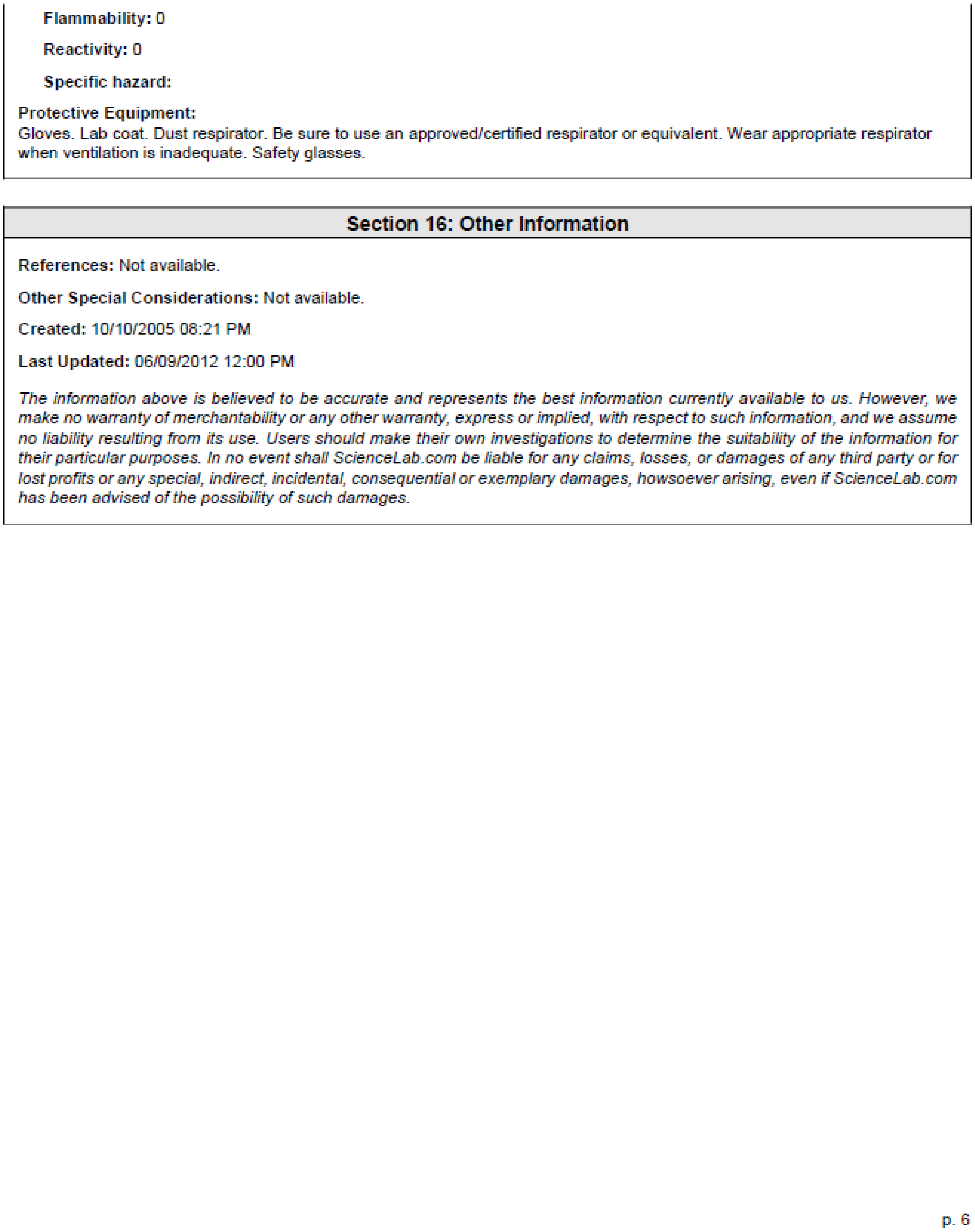
Fire Hazard: 0

Reactivity: 0

Personal Protection: E

National Fire Protection Association (U.S.A.):

Health: 1



Flammability: 0

Reactivity: 0

Specific hazard:

Protective Equipment:
Gloves. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Wear appropriate respirator when ventilation is inadequate. Safety glasses.

Section 16: Other Information

References: Not available.

Other Special Considerations: Not available.

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Health	2
Fire	0
Reactivity	0
Personal Protection	E

Material Safety Data Sheet

Nickel metal MSDS

Section 1: Chemical Product and Company Identification

Product Name: Nickel metal

Catalog Codes: SLN2296, SLN1342, SLN1954

CAS#: 7440-02-0

RTECS: QR5950000

TSCA: TSCA 8(b) inventory: Nickel metal

CI#: Not applicable.

Synonym: Nickel Metal shot; Nickel metal foil.

Chemical Name: Nickel

Chemical Formula: Ni

Contact Information:

Sciencelab.com, Inc.
14025 Smith Rd.
Houston, Texas 77396
US Sales: **1-800-901-7247**
International Sales: **1-281-441-4400**
Order Online: ScienceLab.com

CHEMTREC (24HR Emergency Telephone), call:
1-800-424-9300

International CHEMTREC, call: 1-703-527-3887

For non-emergency assistance, call: 1-281-441-4400

Section 2: Composition and Information on Ingredients

Composition:

Name	CAS #	% by Weight
Nickel metal	7440-02-0	100

Toxicological Data on Ingredients: Nickel metal LD50: Not available. LC50: Not available.

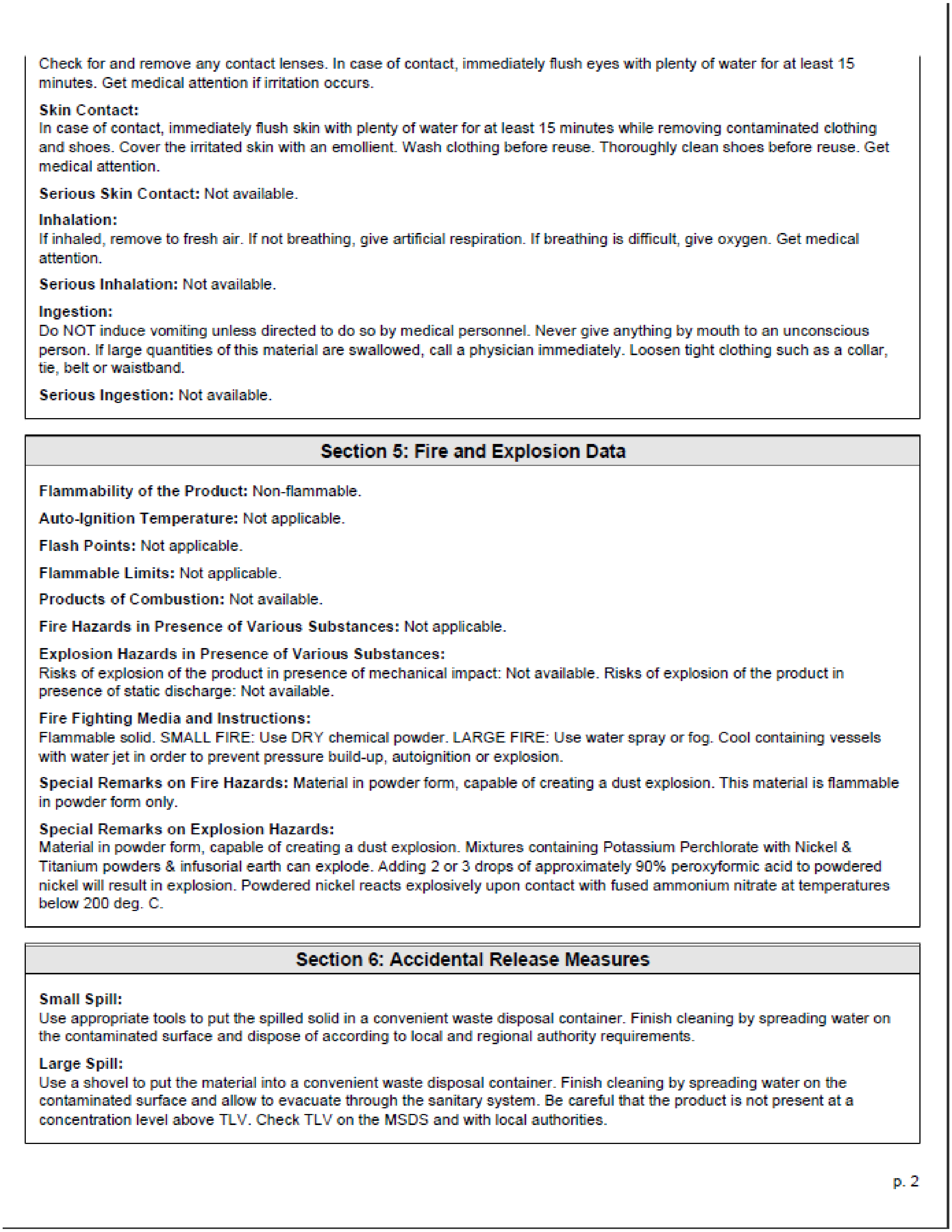
Section 3: Hazards Identification

Potential Acute Health Effects:
Hazardous in case of inhalation. Slightly hazardous in case of skin contact (irritant, sensitizer), of eye contact (irritant), of ingestion.

Potential Chronic Health Effects:
Slightly hazardous in case of skin contact (sensitizer), of ingestion, of inhalation (lung sensitizer). CARCINOGENIC EFFECTS: Classified 2B (Possible for human.) by IARC. Classified 2 (Some evidence.) by NTP. MUTAGENIC EFFECTS: Not available. TERATOGENIC EFFECTS: Not available. DEVELOPMENTAL TOXICITY: Not available. The substance is toxic to skin. The substance may be toxic to kidneys, lungs, liver, upper respiratory tract. Repeated or prolonged exposure to the substance can produce target organs damage.

Section 4: First Aid Measures

Eye Contact:



Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Get medical attention if irritation occurs.

Skin Contact:
In case of contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Cover the irritated skin with an emollient. Wash clothing before reuse. Thoroughly clean shoes before reuse. Get medical attention.

Serious Skin Contact: Not available.

Inhalation:
If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention.

Serious Inhalation: Not available.

Ingestion:
Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. If large quantities of this material are swallowed, call a physician immediately. Loosen tight clothing such as a collar, tie, belt or waistband.

Serious Ingestion: Not available.

Section 5: Fire and Explosion Data

Flammability of the Product: Non-flammable.

Auto-Ignition Temperature: Not applicable.

Flash Points: Not applicable.

Flammable Limits: Not applicable.

Products of Combustion: Not available.

Fire Hazards in Presence of Various Substances: Not applicable.

Explosion Hazards in Presence of Various Substances:
Risks of explosion of the product in presence of mechanical impact: Not available. Risks of explosion of the product in presence of static discharge: Not available.

Fire Fighting Media and Instructions:
Flammable solid. SMALL FIRE: Use DRY chemical powder. LARGE FIRE: Use water spray or fog. Cool containing vessels with water jet in order to prevent pressure build-up, autoignition or explosion.

Special Remarks on Fire Hazards: Material in powder form, capable of creating a dust explosion. This material is flammable in powder form only.

Special Remarks on Explosion Hazards:
Material in powder form, capable of creating a dust explosion. Mixtures containing Potassium Perchlorate with Nickel & Titanium powders & infusorial earth can explode. Adding 2 or 3 drops of approximately 90% peroxyformic acid to powdered nickel will result in explosion. Powdered nickel reacts explosively upon contact with fused ammonium nitrate at temperatures below 200 deg. C.

Section 6: Accidental Release Measures

Small Spill:
Use appropriate tools to put the spilled solid in a convenient waste disposal container. Finish cleaning by spreading water on the contaminated surface and dispose of according to local and regional authority requirements.

Large Spill:
Use a shovel to put the material into a convenient waste disposal container. Finish cleaning by spreading water on the contaminated surface and allow to evacuate through the sanitary system. Be careful that the product is not present at a concentration level above TLV. Check TLV on the MSDS and with local authorities.

Section 7: Handling and Storage

Precautions:
Keep locked up.. Do not breathe dust. Wear suitable protective clothing. In case of insufficient ventilation, wear suitable respiratory equipment. If you feel unwell, seek medical attention and show the label when possible. Keep away from incompatibles such as oxidizing agents, combustible materials, metals, acids.

Storage: Keep container tightly closed. Keep container in a cool, well-ventilated area.

Section 8: Exposure Controls/Personal Protection

Engineering Controls:
Use process enclosures, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. If user operations generate dust, fume or mist, use ventilation to keep exposure to airborne contaminants below the exposure limit.

Personal Protection: Safety glasses. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Gloves.

Personal Protection in Case of a Large Spill:
Splash goggles. Full suit. Dust respirator. Boots. Gloves. A self contained breathing apparatus should be used to avoid inhalation of the product. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.

Exposure Limits:
TWA: 1 (mg/m3) from ACGIH (TLV) [United States] Inhalation Respirable. TWA: 0.5 (mg/m3) [United Kingdom (UK)] TWA: 1 (mg/m3) from OSHA (PEL) [United States] InhalationConsult local authorities for acceptable exposure limits.

Section 9: Physical and Chemical Properties

Physical state and appearance: Solid. (Metal solid. Lustrous solid.)

Odor: Odorless.

Taste: Not available.

Molecular Weight: 58.71 g/mole

Color: Silvery.

pH (1% soln/water): Not applicable.

Boiling Point: 2730°C (4946°F)

Melting Point: 1455°C (2651°F)

Critical Temperature: Not available.

Specific Gravity: Density: 8.908 (Water = 1)

Vapor Pressure: Not applicable.

Vapor Density: Not available.

Volatility: Not available.

Odor Threshold: Not available.

Water/Oil Dist. Coeff.: Not available.

Ionicity (in Water): Not available.

Dispersion Properties: Not available.

Solubility:

Insoluble in cold water, hot water. Insoluble in Ammonia. Soluble in dilute Nitric Acid. Slightly soluble in Hydrochloric Acid, Sulfuric Acid.

Section 10: Stability and Reactivity Data

Stability: The product is stable.

Instability Temperature: Not available.

Conditions of Instability: Incompatible materials

Incompatibility with various substances: Reactive with oxidizing agents, combustible materials, metals, acids.

Corrosivity: Non-corrosive in presence of glass.

Special Remarks on Reactivity:
Incompatible with strong acids, selenium, sulfur, wood and other combustibles, nickel nitrate, aluminum, aluminum trichloride, ethylene, p-dioxan, hydrogen, methanol, non-metals, oxidants, sulfur compounds, aniline, hydrogen sulfide, flammable solvents, hydrazine, and metal powders (especially zinc, aluminum, and magnesium), ammonium nitrate, nitryl fluoride, bromine pentafluoride, potassium perchlorate + titanium powder + indusorial earth.

Special Remarks on Corrosivity: Not available.

Polymerization: Will not occur.

Section 11: Toxicological Information

Routes of Entry: Inhalation. Ingestion.

Toxicity to Animals:
LD50: Not available. LC50: Not available.

Chronic Effects on Humans:
CARCINOGENIC EFFECTS: Classified 2B (Possible for human.) by IARC. Classified 2 (Some evidence.) by NTP. Causes damage to the following organs: skin. May cause damage to the following organs: kidneys, lungs, liver, upper respiratory tract.

Other Toxic Effects on Humans:
Hazardous in case of inhalation. Slightly hazardous in case of skin contact (irritant, sensitizer), of ingestion.

Special Remarks on Toxicity to Animals:
Lowest Published Lethal Dose/Conc: LDL [Rat] - Route: Oral; Dose: 5000 mg/kg LDL [Guinea Pig] - Route: Oral; Dose: 5000 mg/kg

Special Remarks on Chronic Effects on Humans: May cause cancer based on animal test data

Special Remarks on other Toxic Effects on Humans:
Acute Potential Health Effects: Skin: Nickel dust and fume can irritate skin. Eyes: Nickel dust and fume can irritate eyes. Inhalation: Inhalation of dust or fume may cause respiratory tract irritation with non-productive cough, hoarseness, sore throat, headache, vertigo, weakness, chest pain, followed by delayed effects, including tachypnea, dyspnea, and ARDS. Death due to ARDS has been reported following inhalation of high concentrations of respirable metallic nickel dust. Later effects may include pulmonary edema and fibrosis. Ingestion: Metallic nickel is generally considered not to be acutely toxic if ingested. Ingestion may cause nausea, vomiting, abdominal , and diarrhea. Nickel may damage the kidneys(proteinuria), and may affect liver function. It may also affect behavior (somnolence), and cardiovascular system (increased cornary artery resistance, decreased myocardial contractility, myocardial damage, regional or general arteriolar or venus dilation). Chronic Potential Health Effects: Skin: May cause skin allergy. Nickel and nickel compounds are among the most common sensitizers inducing allergic contact dermatitis. Inhalation: Chronic inhalation nickel dust or fume can cause chronic hypertrophic rhinitis, sinusitis, nasal polyps, perforation of the nasal septum, chronic pulmonary irritation, fibrosis, pulmonary edema, pulmonary eosinophilia, Pneumoconiosis, allergies (asthma-like allergy), and cancer of the nasal sinus cavities, lungs, and possibly other organs. Future exposures can cause asthma attacks with shortness of breath, wheezing, cough, and/or chest tightness. Chronic inhalation of nickel dust or fume may also affect the liver (impaired liver function tests), and blood (changes in red blood cell count). Ingestion: Prolonged or repeated ingestion of nickel can be a source chronic urticaria and other signs of allergy.

Chronic ingestion of NIckel may also affect respiration and cause pneumoconiosis or fibrosis. Note: In the general population, sensitization occurs from exposure to nickel-containing coins, jewelry, watches,

Section 12: Ecological Information

Ecotoxicity: Not available.

BOD5 and COD: Not available.

Products of Biodegradation:
Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

Toxicity of the Products of Biodegradation: The products of degradation are as toxic as the original product.

Special Remarks on the Products of Biodegradation: Not available.

Section 13: Disposal Considerations

Waste Disposal:
Waste must be disposed of in accordance with federal, state and local environmental control regulations.

Section 14: Transport Information

DOT Classification: Not a DOT controlled material (United States).

Identification: Not applicable.

Special Provisions for Transport: Not applicable.

Section 15: Other Regulatory Information

Federal and State Regulations:
California prop. 65: This product contains the following ingredients for which the State of California has found to cause cancer, birth defects or other reproductive harm, which would require a warning under the statute: Nickel metal California prop. 65: This product contains the following ingredients for which the State of California has found to cause cancer which would require a warning under the statute: Nickel metal Connecticut hazardous material survey.: Nickel metal Illinois toxic substances disclosure to employee act: Nickel metal Illinois chemical safety act: Nickel metal New York release reporting list: Nickel metal Rhode Island RTK hazardous substances: Nickel metal Pennsylvania RTK: Nickel metal Michigan critical material: Nickel metal Massachusetts RTK: Nickel metal Massachusetts spill list: Nickel metal New Jersey: Nickel metal New Jersey spill list: Nickel metal Louisiana spill reporting: Nickel metal California Director's List of Hazardous Substances: Nickel metal TSCA 8(b) inventory: Nickel metal

Other Regulations:
OSHA: Hazardous by definition of Hazard Communication Standard (29 CFR 1910.1200). EINECS: This product is on the European Inventory of Existing Commercial Chemical Substances.

Other Classifications:

WHMIS (Canada): CLASS D-2A: Material causing other toxic effects (VERY TOXIC).

DSCL (EEC):
R40- Possible risks of irreversible effects. R43- May cause sensitization by skin contact. S22- Do not breathe dust. S36- Wear suitable protective clothing.

HMIS (U.S.A.):

Health Hazard: 2

Fire Hazard: 0

Reactivity: 0

Personal Protection: E

National Fire Protection Association (U.S.A.):

Health: 2

Flammability: 0

Reactivity: 0

Specific hazard:

Protective Equipment:
Gloves. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Wear appropriate respirator when ventilation is inadequate. Safety glasses.

Section 16: Other Information

References: Not available.

Other Special Considerations: Not available.

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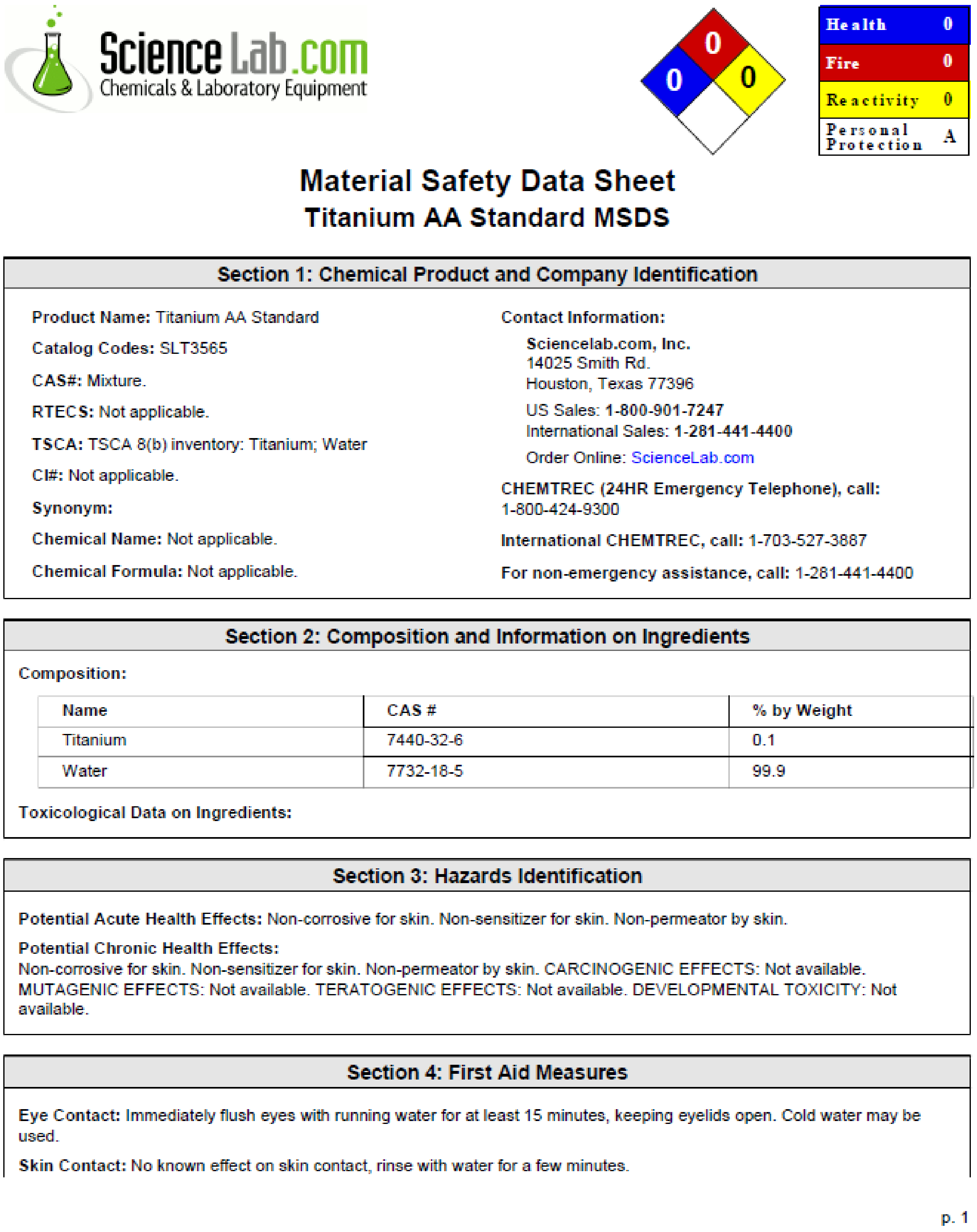

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Chemicals & Laboratory Equipment

Health	0
Fire	0
Reactivity	0
Personal Protection	A

Material Safety Data Sheet
Titanium AA Standard MSDS

Section 1: Chemical Product and Company Identification

Product Name: Titanium AA Standard

Catalog Codes: SLT3565

CAS#: Mixture.

RTECS: Not applicable.

TSCA: TSCA 8(b) inventory: Titanium; Water

CI#: Not applicable.

Synonym:

Chemical Name: Not applicable.

Chemical Formula: Not applicable.

Contact Information:

Sciencelab.com, Inc.
14025 Smith Rd.
Houston, Texas 77396

US Sales: **1-800-901-7247**
International Sales: **1-281-441-4400**

Order Online: ScienceLab.com

CHEMTREC (24HR Emergency Telephone), call:
1-800-424-9300

International CHEMTREC, call: 1-703-527-3887

For non-emergency assistance, call: 1-281-441-4400

Section 2: Composition and Information on Ingredients

Composition:

Name	CAS #	% by Weight
Titanium	7440-32-6	0.1
Water	7732-18-5	99.9

Toxicological Data on Ingredients:

Section 3: Hazards Identification

Potential Acute Health Effects: Non-corrosive for skin. Non-sensitizer for skin. Non-permeator by skin.

Potential Chronic Health Effects:
Non-corrosive for skin. Non-sensitizer for skin. Non-permeator by skin. CARCINOGENIC EFFECTS: Not available. MUTAGENIC EFFECTS: Not available. TERATOGENIC EFFECTS: Not available. DEVELOPMENTAL TOXICITY: Not available.

Section 4: First Aid Measures

Eye Contact: Immediately flush eyes with running water for at least 15 minutes, keeping eyelids open. Cold water may be used.

Skin Contact: No known effect on skin contact, rinse with water for a few minutes.

Serious Skin Contact: Not available.

Inhalation: Allow the victim to rest in a well ventilated area. Seek immediate medical attention.

Serious Inhalation: Not available.

Ingestion:
Do not induce vomiting. Loosen tight clothing such as a collar, tie, belt or waistband. If the victim is not breathing, perform mouth-to-mouth resuscitation. Seek immediate medical attention.

Serious Ingestion: Not available.

Section 5: Fire and Explosion Data

Flammability of the Product: Non-flammable.

Auto-Ignition Temperature: Not applicable.

Flash Points: Not applicable.

Flammable Limits: Not applicable.

Products of Combustion: Not available.

Fire Hazards in Presence of Various Substances: Not applicable.

Explosion Hazards in Presence of Various Substances:
Risks of explosion of the product in presence of mechanical impact: Not available. Risks of explosion of the product in presence of static discharge: Not available.

Fire Fighting Media and Instructions: Not applicable.

Special Remarks on Fire Hazards: Not available.

Special Remarks on Explosion Hazards: Not available.

Section 6: Accidental Release Measures

Small Spill:
Dilute with water and mop up, or absorb with an inert dry material and place in an appropriate waste disposal container. Finish cleaning by spreading water on the contaminated surface and dispose of according to local and regional authority requirements.

Large Spill:
Absorb with an inert material and put the spilled material in an appropriate waste disposal. Finish cleaning by spreading water on the contaminated surface and allow to evacuate through the sanitary system.

Section 7: Handling and Storage

Precautions: No specific safety phrase has been found applicable for this product.

Storage:
No specific storage is required. Use shelves or cabinets sturdy enough to bear the weight of the chemicals. Be sure that it is not necessary to strain to reach materials, and that shelves are not overloaded.

Section 8: Exposure Controls/Personal Protection

Engineering Controls:
Provide exhaust ventilation or other engineering controls to keep the airborne concentrations of vapors below their respective threshold limit value.

Personal Protection: Safety glasses. Lab coat.

Personal Protection in Case of a Large Spill:
Splash goggles. Full suit. Boots. Gloves. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.

Exposure Limits: Not available.

Section 9: Physical and Chemical Properties

Physical state and appearance: Liquid.

Odor: Not available.

Taste: Not available.

Molecular Weight: Not applicable.

Color: Not available.

pH (1% soln/water): Neutral.

Boiling Point: The lowest known value is 100°C (212°F) (Water).

Melting Point: Not available.

Critical Temperature: Not available.

Specific Gravity: The only known value is 1 (Water = 1) (Water).

Vapor Pressure: The highest known value is 17.535 mm of Hg (@ 20°C) (Water).

Vapor Density: The highest known value is 0.62 (Air = 1) (Water).

Volatility: Not available.

Odor Threshold: Not available.

Water/Oil Dist. Coeff.: Not available.

Ionicity (in Water): Not available.

Dispersion Properties: See solubility in water.

Solubility: Easily soluble in cold water.

Section 10: Stability and Reactivity Data

Stability: The product is stable.

Instability Temperature: Not available.

Conditions of Instability: Not available.

Incompatibility with various substances: Not available.

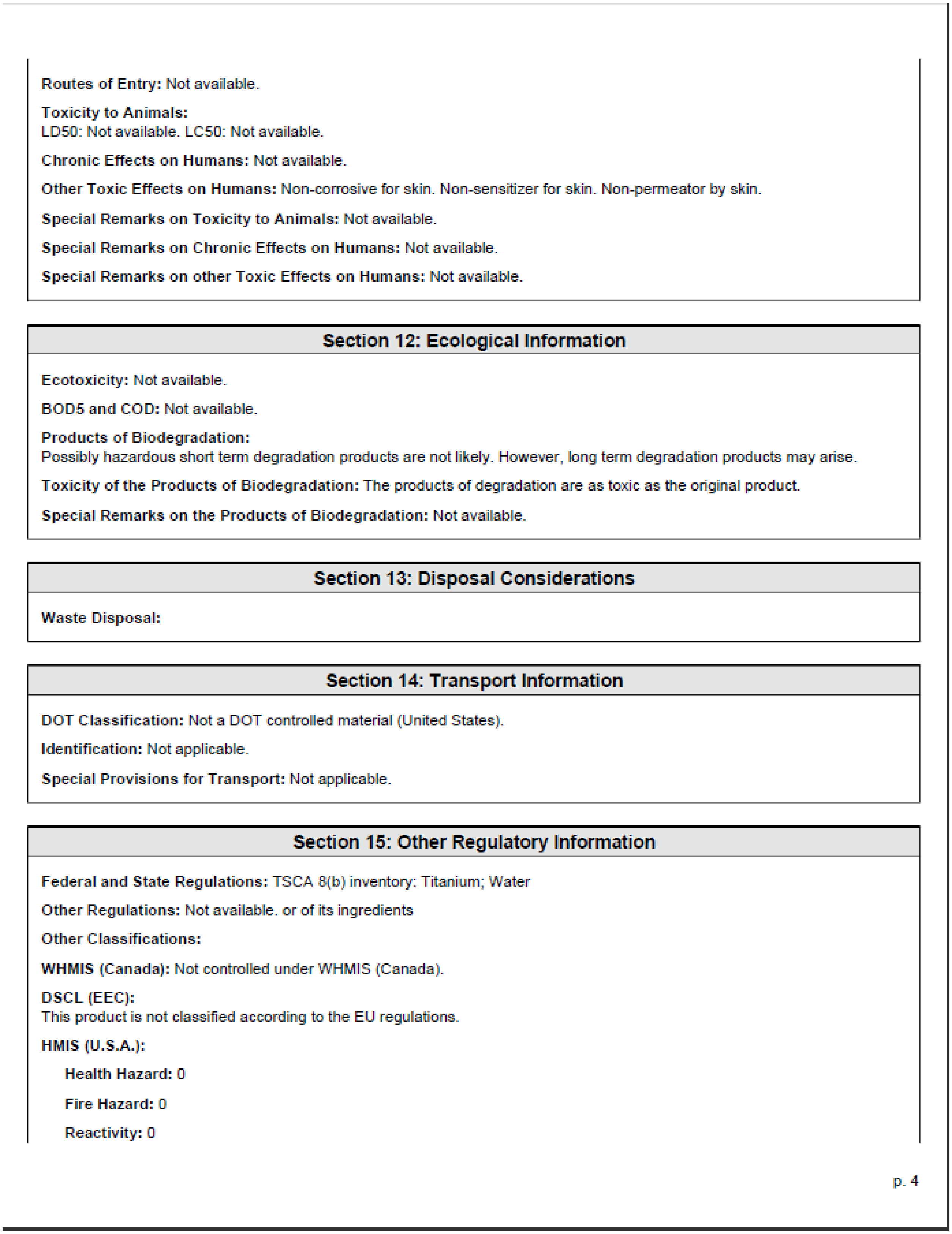
Corrosivity: Non-corrosive in presence of glass.

Special Remarks on Reactivity: Not available.

Special Remarks on Corrosivity: Not available.

Polymerization: No.

Section 11: Toxicological Information



Routes of Entry: Not available.

Toxicity to Animals:
LD50: Not available. LC50: Not available.

Chronic Effects on Humans: Not available.

Other Toxic Effects on Humans: Non-corrosive for skin. Non-sensitizer for skin. Non-permeator by skin.

Special Remarks on Toxicity to Animals: Not available.

Special Remarks on Chronic Effects on Humans: Not available.

Special Remarks on other Toxic Effects on Humans: Not available.

Section 12: Ecological Information

Ecotoxicity: Not available.

BOD5 and COD: Not available.

Products of Biodegradation:
Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

Toxicity of the Products of Biodegradation: The products of degradation are as toxic as the original product.

Special Remarks on the Products of Biodegradation: Not available.

Section 13: Disposal Considerations

Waste Disposal:

Section 14: Transport Information

DOT Classification: Not a DOT controlled material (United States).

Identification: Not applicable.

Special Provisions for Transport: Not applicable.

Section 15: Other Regulatory Information

Federal and State Regulations: TSCA 8(b) inventory: Titanium; Water

Other Regulations: Not available. or of its ingredients

Other Classifications:

WHMIS (Canada): Not controlled under WHMIS (Canada).

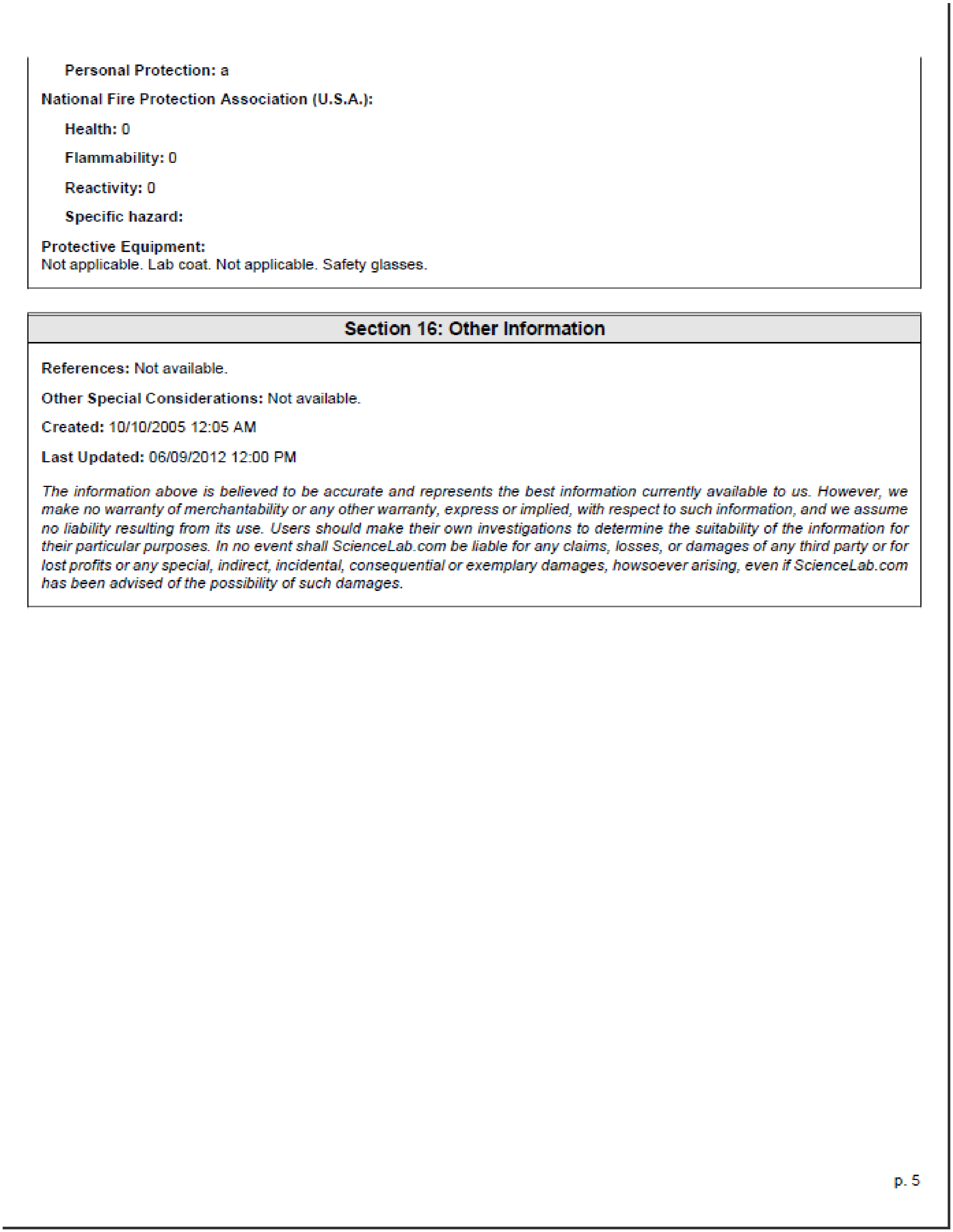
DSCL (EEC):
This product is not classified according to the EU regulations.

HMIS (U.S.A.):

Health Hazard: 0

Fire Hazard: 0

Reactivity: 0



Personal Protection: a

National Fire Protection Association (U.S.A.):

Health: 0

Flammability: 0

Reactivity: 0

Specific hazard:

Protective Equipment:
Not applicable. Lab coat. Not applicable. Safety glasses.

Section 16: Other Information

References: Not available.

Other Special Considerations: Not available.

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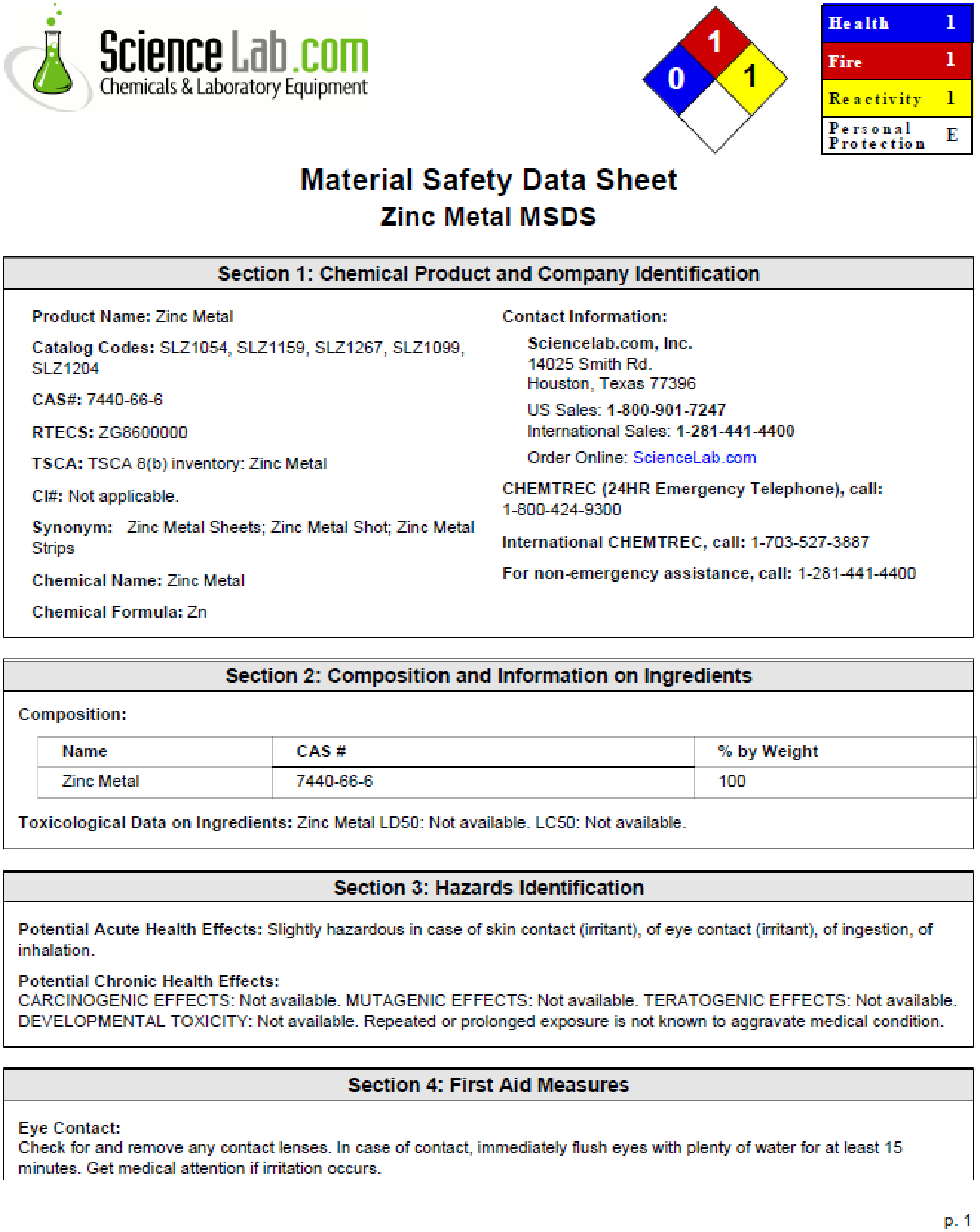


Health	1
Fire	1
Reactivity	1
Personal Protection	E

Material Safety Data Sheet

Zinc Metal MSDS

Section 1: Chemical Product and Company Identification

Product Name: Zinc Metal

Catalog Codes: SLZ1054, SLZ1159, SLZ1267, SLZ1099, SLZ1204

CAS#: 7440-66-6

RTECS: ZG8600000

TSCA: TSCA 8(b) inventory: Zinc Metal

CI#: Not applicable.

Synonym: Zinc Metal Sheets; Zinc Metal Shot; Zinc Metal Strips

Chemical Name: Zinc Metal

Chemical Formula: Zn

Contact Information:

Sciencelab.com, Inc.
14025 Smith Rd.
Houston, Texas 77396

US Sales: **1-800-901-7247**
International Sales: **1-281-441-4400**

Order Online: ScienceLab.com

CHEMTREC (24HR Emergency Telephone), call:
1-800-424-9300

International CHEMTREC, call: 1-703-527-3887

For non-emergency assistance, call: 1-281-441-4400

Section 2: Composition and Information on Ingredients

Composition:

Name	CAS #	% by Weight
Zinc Metal	7440-66-6	100

Toxicological Data on Ingredients: Zinc Metal LD50: Not available. LC50: Not available.

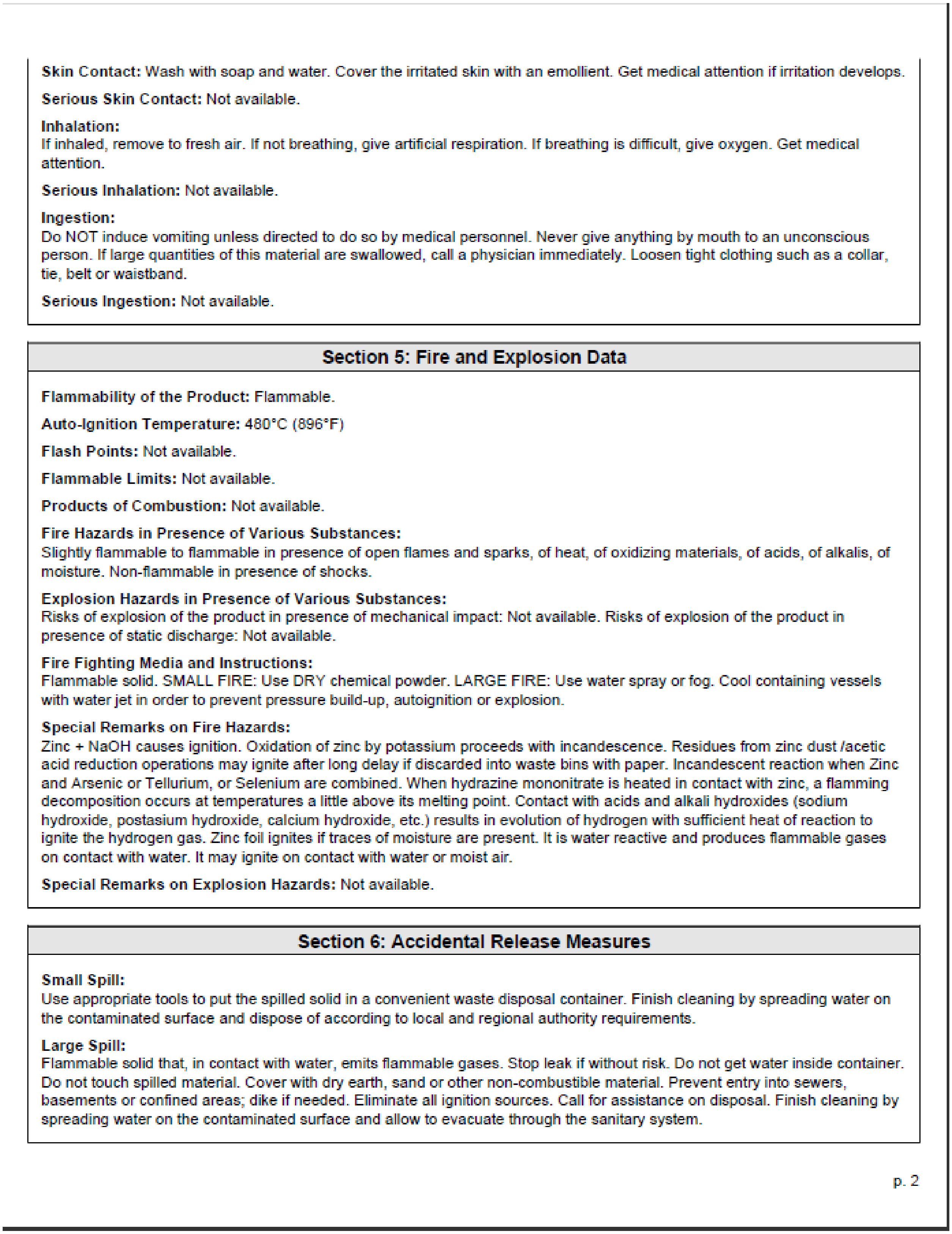
Section 3: Hazards Identification

Potential Acute Health Effects: Slightly hazardous in case of skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation.

Potential Chronic Health Effects:
CARCINOGENIC EFFECTS: Not available. MUTAGENIC EFFECTS: Not available. TERATOGENIC EFFECTS: Not available. DEVELOPMENTAL TOXICITY: Not available. Repeated or prolonged exposure is not known to aggravate medical condition.

Section 4: First Aid Measures

Eye Contact:
Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Get medical attention if irritation occurs.



Skin Contact: Wash with soap and water. Cover the irritated skin with an emollient. Get medical attention if irritation develops.

Serious Skin Contact: Not available.

Inhalation:
If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention.

Serious Inhalation: Not available.

Ingestion:
Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. If large quantities of this material are swallowed, call a physician immediately. Loosen tight clothing such as a collar, tie, belt or waistband.

Serious Ingestion: Not available.

Section 5: Fire and Explosion Data

Flammability of the Product: Flammable.

Auto-Ignition Temperature: 480°C (896°F)

Flash Points: Not available.

Flammable Limits: Not available.

Products of Combustion: Not available.

Fire Hazards in Presence of Various Substances:
Slightly flammable to flammable in presence of open flames and sparks, of heat, of oxidizing materials, of acids, of alkalis, of moisture. Non-flammable in presence of shocks.

Explosion Hazards in Presence of Various Substances:
Risks of explosion of the product in presence of mechanical impact: Not available. Risks of explosion of the product in presence of static discharge: Not available.

Fire Fighting Media and Instructions:
Flammable solid. SMALL FIRE: Use DRY chemical powder. LARGE FIRE: Use water spray or fog. Cool containing vessels with water jet in order to prevent pressure build-up, autoignition or explosion.

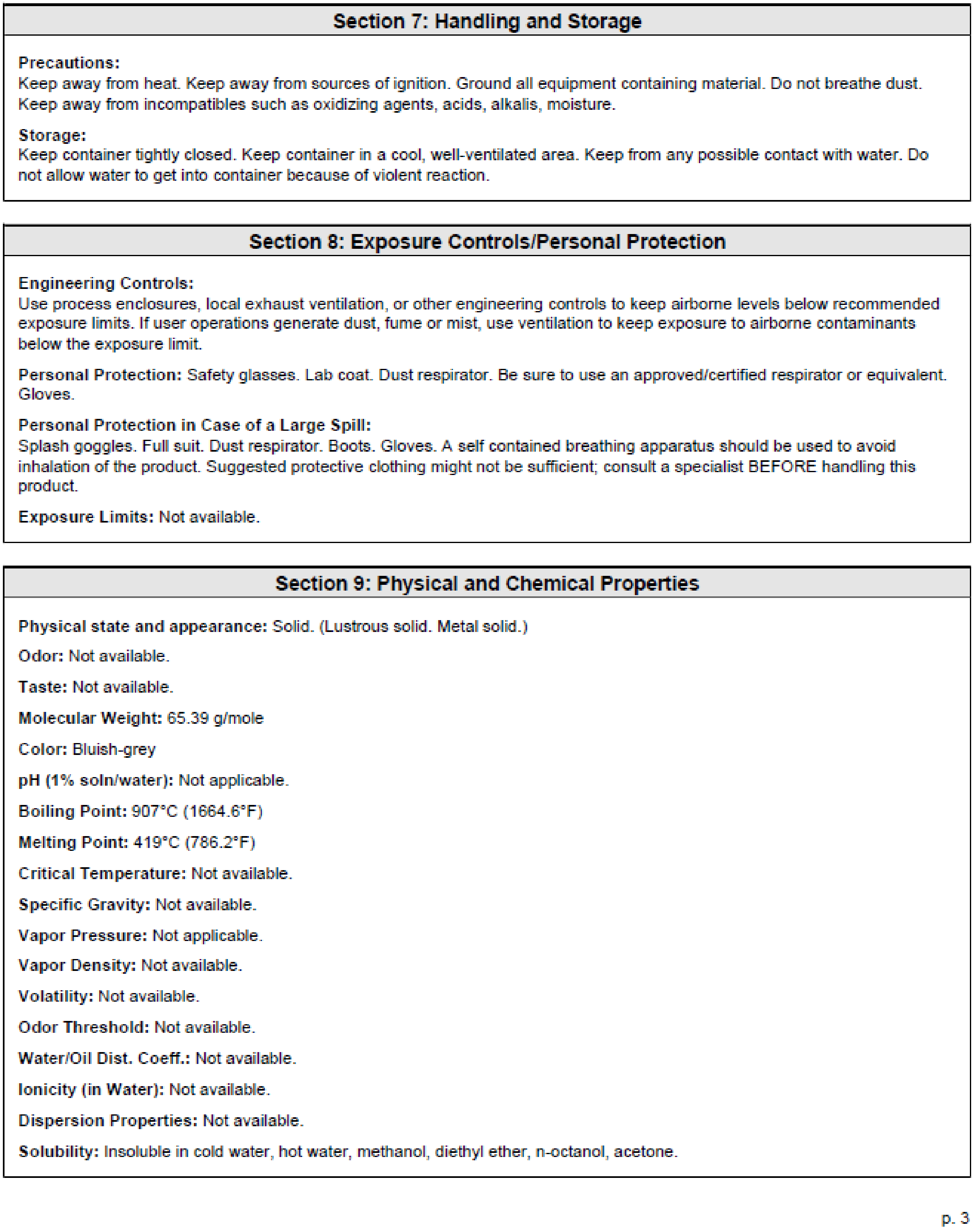
Special Remarks on Fire Hazards:
Zinc + NaOH causes ignition. Oxidation of zinc by potassium proceeds with incandescence. Residues from zinc dust /acetic acid reduction operations may ignite after long delay if discarded into waste bins with paper. Incandescent reaction when Zinc and Arsenic or Tellurium, or Selenium are combined. When hydrazine mononitrate is heated in contact with zinc, a flamming decomposition occurs at temperatures a little above its melting point. Contact with acids and alkali hydroxides (sodium hydroxide, postasium hydroxide, calcium hydroxide, etc.) results in evolution of hydrogen with sufficient heat of reaction to ignite the hydrogen gas. Zinc foil ignites if traces of moisture are present. It is water reactive and produces flammable gases on contact with water. It may ignite on contact with water or moist air.

Special Remarks on Explosion Hazards: Not available.

Section 6: Accidental Release Measures

Small Spill:
Use appropriate tools to put the spilled solid in a convenient waste disposal container. Finish cleaning by spreading water on the contaminated surface and dispose of according to local and regional authority requirements.

Large Spill:
Flammable solid that, in contact with water, emits flammable gases. Stop leak if without risk. Do not get water inside container. Do not touch spilled material. Cover with dry earth, sand or other non-combustible material. Prevent entry into sewers, basements or confined areas; dike if needed. Eliminate all ignition sources. Call for assistance on disposal. Finish cleaning by spreading water on the contaminated surface and allow to evacuate through the sanitary system.



Section 7: Handling and Storage

Precautions:
Keep away from heat. Keep away from sources of ignition. Ground all equipment containing material. Do not breathe dust. Keep away from incompatibles such as oxidizing agents, acids, alkalis, moisture.

Storage:
Keep container tightly closed. Keep container in a cool, well-ventilated area. Keep from any possible contact with water. Do not allow water to get into container because of violent reaction.

Section 8: Exposure Controls/Personal Protection

Engineering Controls:
Use process enclosures, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. If user operations generate dust, fume or mist, use ventilation to keep exposure to airborne contaminants below the exposure limit.

Personal Protection: Safety glasses. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Gloves.

Personal Protection in Case of a Large Spill:
Splash goggles. Full suit. Dust respirator. Boots. Gloves. A self contained breathing apparatus should be used to avoid inhalation of the product. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.

Exposure Limits: Not available.

Section 9: Physical and Chemical Properties

Physical state and appearance: Solid. (Lustrous solid. Metal solid.)

Odor: Not available.

Taste: Not available.

Molecular Weight: 65.39 g/mole

Color: Bluish-grey

pH (1% soln/water): Not applicable.

Boiling Point: 907°C (1664.6°F)

Melting Point: 419°C (786.2°F)

Critical Temperature: Not available.

Specific Gravity: Not available.

Vapor Pressure: Not applicable.

Vapor Density: Not available.

Volatility: Not available.

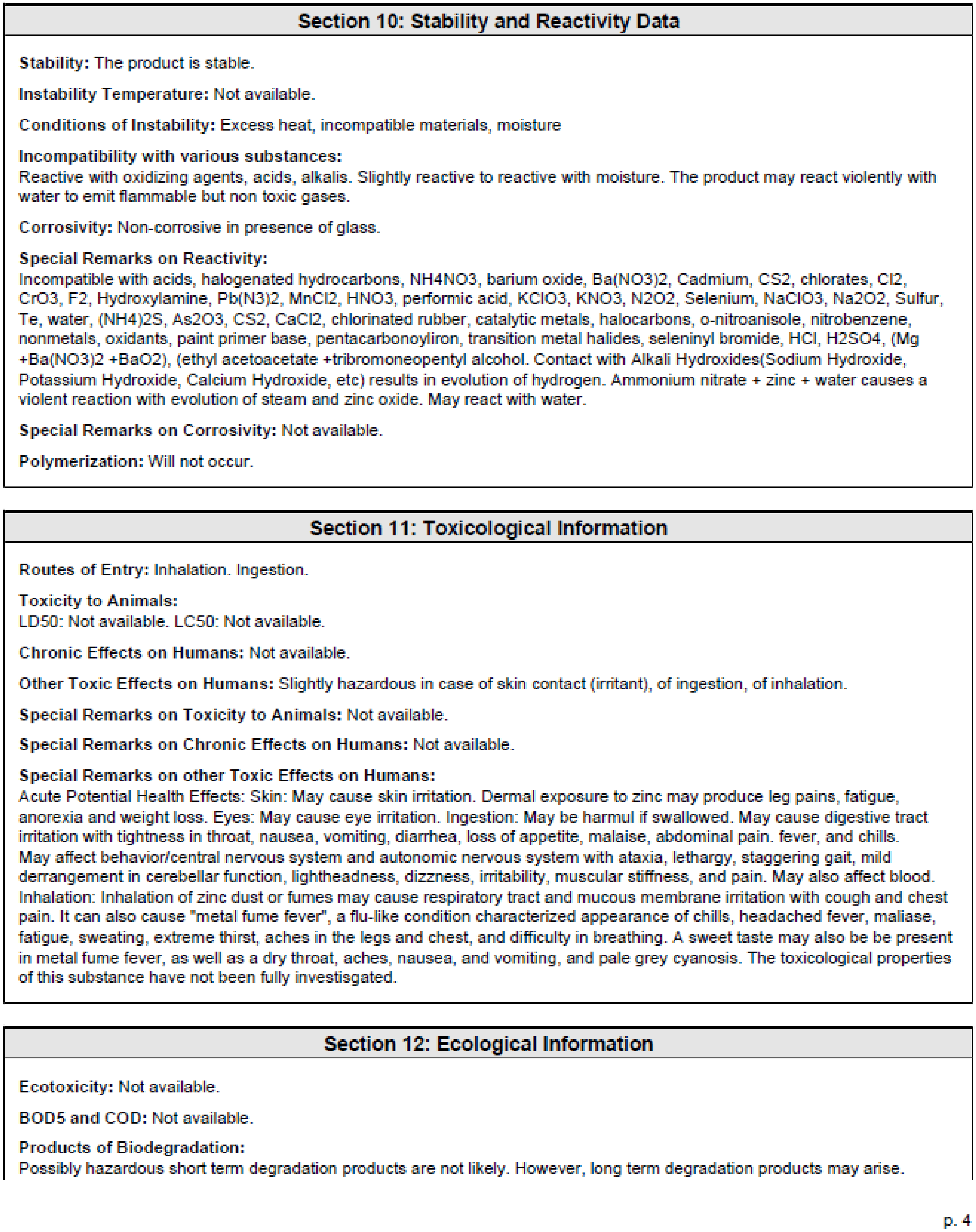
Odor Threshold: Not available.

Water/Oil Dist. Coeff.: Not available.

Ionicity (in Water): Not available.

Dispersion Properties: Not available.

Solubility: Insoluble in cold water, hot water, methanol, diethyl ether, n-octanol, acetone.



Section 10: Stability and Reactivity Data

Stability: The product is stable.

Instability Temperature: Not available.

Conditions of Instability: Excess heat, incompatible materials, moisture

Incompatibility with various substances:
Reactive with oxidizing agents, acids, alkalis. Slightly reactive to reactive with moisture. The product may react violently with water to emit flammable but non toxic gases.

Corrosivity: Non-corrosive in presence of glass.

Special Remarks on Reactivity:
Incompatible with acids, halogenated hydrocarbons, NH4NO3, barium oxide, Ba(NO3)2, Cadmium, CS2, chlorates, Cl2, CrO3, F2, Hydroxylamine, Pb(N3)2, MnCl2, HNO3, performic acid, KClO3, KNO3, N2O2, Selenium, NaClO3, Na2O2, Sulfur, Te, water, (NH4)2S, As2O3, CS2, CaCl2, chlorinated rubber, catalytic metals, halocarbons, o-nitroanisole, nitrobenzene, nonmetals, oxidants, paint primer base, pentacarbonoyliron, transition metal halides, seleninyl bromide, HCl, H2SO4, (Mg +Ba(NO3)2 +BaO2), (ethyl acetoacetate +tribromoneopentyl alcohol. Contact with Alkali Hydroxides(Sodium Hydroxide, Potassium Hydroxide, Calcium Hydroxide, etc) results in evolution of hydrogen. Ammonium nitrate + zinc + water causes a violent reaction with evolution of steam and zinc oxide. May react with water.

Special Remarks on Corrosivity: Not available.

Polymerization: Will not occur.

Section 11: Toxicological Information

Routes of Entry: Inhalation. Ingestion.

Toxicity to Animals:
LD50: Not available. LC50: Not available.

Chronic Effects on Humans: Not available.

Other Toxic Effects on Humans: Slightly hazardous in case of skin contact (irritant), of ingestion, of inhalation.

Special Remarks on Toxicity to Animals: Not available.

Special Remarks on Chronic Effects on Humans: Not available.

Special Remarks on other Toxic Effects on Humans:
Acute Potential Health Effects: Skin: May cause skin irritation. Dermal exposure to zinc may produce leg pains, fatigue, anorexia and weight loss. Eyes: May cause eye irritation. Ingestion: May be harmul if swallowed. May cause digestive tract irritation with tightness in throat, nausea, vomiting, diarrhea, loss of appetite, malaise, abdominal pain. fever, and chills.
May affect behavior/central nervous system and autonomic nervous system with ataxia, lethargy, staggering gait, mild derrangement in cerebellar function, lightheadness, dizzness, irritability, muscular stiffness, and pain. May also affect blood.
Inhalation: Inhalation of zinc dust or fumes may cause respiratory tract and mucous membrane irritation with cough and chest pain. It can also cause "metal fume fever", a flu-like condition characterized appearance of chills, headached fever, maliase, fatigue, sweating, extreme thirst, aches in the legs and chest, and difficulty in breathing. A sweet taste may also be be present in metal fume fever, as well as a dry throat, aches, nausea, and vomiting, and pale grey cyanosis. The toxicological properties of this substance have not been fully investisgated.

Section 12: Ecological Information

Ecotoxicity: Not available.

BOD5 and COD: Not available.

Products of Biodegradation:
Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

Toxicity of the Products of Biodegradation: Not available.

Special Remarks on the Products of Biodegradation: Not available.

Section 13: Disposal Considerations

Waste Disposal:
Waste must be disposed of in accordance with federal, state and local environmental control regulations.

Section 14: Transport Information

DOT Classification: Not a DOT controlled material (United States).

Identification: Not applicable.

Special Provisions for Transport: Not applicable.

Section 15: Other Regulatory Information

Federal and State Regulations:
New York release reporting list: Zinc Metal Rhode Island RTK hazardous substances: Zinc Metal Pennsylvania RTK: Zinc Metal Florida: Zinc Metal Michigan critical material: Zinc Metal Massachusetts RTK: Zinc Metal New Jersey: Zinc Metal California Director's List of Hazardous Substances: Zinc Metal TSCA 8(b) inventory: Zinc Metal TSCA 12(b) one time export: Zinc Metal SARA 313 toxic chemical notification and release reporting: Zinc Metal CERCLA: Hazardous substances.: Zinc Metal: 1000 lbs. (453.6 kg)

Other Regulations: EINECS: This product is on the European Inventory of Existing Commercial Chemical Substances.

Other Classifications:

WHMIS (Canada): Not Available

DSCL (EEC):
R15- Contact with water liberates extremely flammable gases. R17- Spontaneously flammable in air. S7/8- Keep container tightly closed and dry.

HMIS (U.S.A.):

- **Health Hazard:** 1
- **Fire Hazard:** 1
- **Reactivity:** 1
- **Personal Protection:** E

National Fire Protection Association (U.S.A.):

- **Health:** 0
- **Flammability:** 1
- **Reactivity:** 1
- **Specific hazard:**

Protective Equipment:
Gloves. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Safety glasses.

Section 16: Other Information

References: Not available.

Other Special Considerations: Not available.

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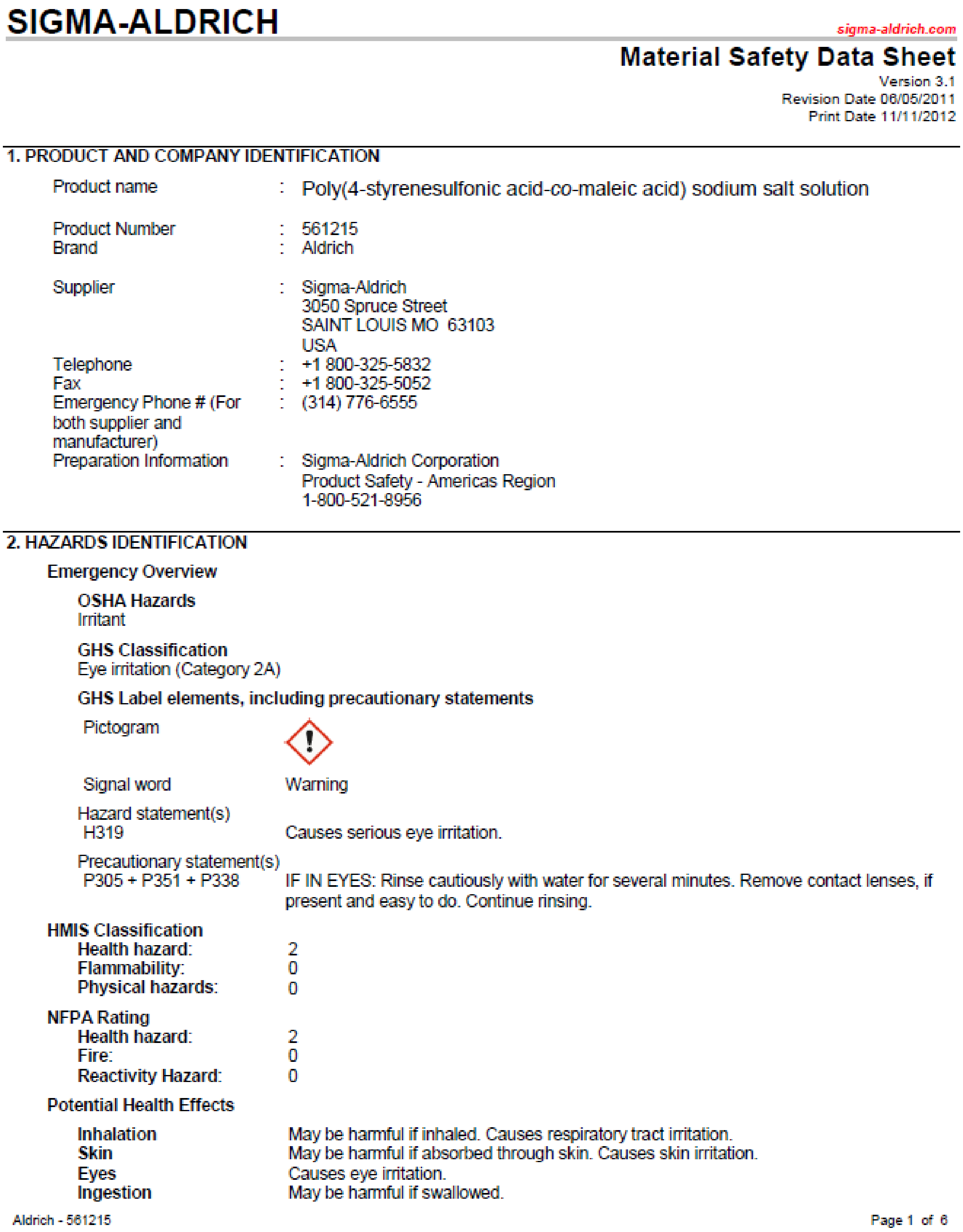
Last Updated: 06/09/2012 12:00 PM

Poly(4-styrenesulfonic acid-*co*-maleic acid) sodium salt solution



SIGMA-ALDRICH sigma-aldrich.com

Material Safety Data Sheet
Version 3.1
Revision Date 06/05/2011
Print Date 11/11/2012

1. PRODUCT AND COMPANY IDENTIFICATION

Product name	:	Poly(4-styrenesulfonic acid-*co*-maleic acid) sodium salt solution
Product Number	:	561215
Brand	:	Aldrich
Supplier	:	Sigma-Aldrich 3050 Spruce Street SAINT LOUIS MO 63103 USA
Telephone	:	+1 800-325-5832
Fax	:	+1 800-325-5052
Emergency Phone # (For both supplier and manufacturer)	:	(314) 776-6555
Preparation Information	:	Sigma-Aldrich Corporation Product Safety - Americas Region 1-800-521-8956

2. HAZARDS IDENTIFICATION

Emergency Overview

OSHA Hazards
Irritant

GHS Classification
Eye irritation (Category 2A)

GHS Label elements, including precautionary statements

Pictogram	!
Signal word	Warning
Hazard statement(s)	
H319	Causes serious eye irritation.
Precautionary statement(s)	
P305 + P351 + P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.

HMIS Classification

Health hazard:	2
Flammability:	0
Physical hazards:	0

NFPA Rating

Health hazard:	2
Fire:	0
Reactivity Hazard:	0

Potential Health Effects

Inhalation	May be harmful if inhaled. Causes respiratory tract irritation.
Skin	May be harmful if absorbed through skin. Causes skin irritation.
Eyes	Causes eye irritation.
Ingestion	May be harmful if swallowed.

Aldrich - 561215 Page 1 of 6

3. COMPOSITION/INFORMATION ON INGREDIENTS

CAS-No.	EC-No.	Index-No.	Concentration
Poly(4-styrenesulfonic acid-co-maleic acid) sodium salt			
68037-40-1	-	-	25 %
Water			
7732-18-5	231-791-2	-	75 %

4. FIRST AID MEASURES

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance.Move out of dangerous area.

If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

In case of skin contact
Wash off with soap and plenty of water. Consult a physician.

In case of eye contact
Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician.

If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

5. FIRE-FIGHTING MEASURES

Conditions of flammability
Not flammable or combustible.

Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

Special protective equipment for fire-fighters
Wear self contained breathing apparatus for fire fighting if necessary.

Hazardous combustion products
Hazardous decomposition products formed under fire conditions. - Carbon oxides, Sulphur oxides, Sodium oxides

6. ACCIDENTAL RELEASE MEASURES

Personal precautions
Use personal protective equipment. Avoid breathing vapors, mist or gas. Ensure adequate ventilation.

Environmental precautions
Do not let product enter drains.

Methods and materials for containment and cleaning up
Soak up with inert absorbent material and dispose of as hazardous waste. Keep in suitable, closed containers for disposal.

7. HANDLING AND STORAGE

Precautions for safe handling
Avoid contact with skin and eyes. Avoid inhalation of vapour or mist.

Conditions for safe storage
Keep container tightly closed in a dry and well-ventilated place. Containers which are opened must be carefully resealed and kept upright to prevent leakage.

Do not freeze.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Contains no substances with occupational exposure limit values.

Personal protective equipment

Respiratory protection
Where risk assessment shows air-purifying respirators are appropriate use a full-face respirator with multi-purpose combination (US) or type ABEK (EN 14387) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Hand protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Eye protection
Safety glasses with side-shields conforming to EN166 Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin and body protection
impervious clothing, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Hygiene measures
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance

Form	liquid
Colour	no data available

Safety data

pH	no data available
Melting point/freezing point	Melting point/range: 0 °C (32 °F)
Boiling point	100 °C (212 °F) at 1,013 hPa (760 mmHg)
Flash point	no data available
Ignition temperature	no data available
Autoignition temperature	no data available
Lower explosion limit	no data available
Upper explosion limit	no data available
Vapour pressure	23 hPa (17 mmHg) at 20 °C (68 °F)
Density	1.200 g/cm3
Water solubility	no data available
Partition coefficient: n-octanol/water	no data available
Relative vapour density	no data available
Odour	no data available
Odour Threshold	no data available

Evaporation rate 1

10. STABILITY AND REACTIVITY

Chemical stability
Stable under recommended storage conditions.

Possibility of hazardous reactions
no data available

Conditions to avoid
no data available

Materials to avoid
Strong oxidizing agents

Hazardous decomposition products
Hazardous decomposition products formed under fire conditions. - Carbon oxides, Sulphur oxides, Sodium oxides
Other decomposition products - no data available

11. TOXICOLOGICAL INFORMATION

Acute toxicity

Oral LD50
no data available

Inhalation LC50
no data available

Dermal LD50
no data available

Other information on acute toxicity
no data available

Skin corrosion/irritation
no data available

Serious eye damage/eye irritation
Eyes: no data available

Respiratory or skin sensitization
no data available

Germ cell mutagenicity
no data available

Carcinogenicity

IARC:	No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.
ACGIH:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.
NTP:	No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.
OSHA:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

no data available

Teratogenicity

no data available

Specific target organ toxicity - single exposure (Globally Harmonized System)
no data available

Specific target organ toxicity - repeated exposure (Globally Harmonized System)
no data available

Aspiration hazard
no data available

Potential health effects

Inhalation	May be harmful if inhaled. Causes respiratory tract irritation.
Ingestion	May be harmful if swallowed.
Skin	May be harmful if absorbed through skin. Causes skin irritation.
Eyes	Causes eye irritation.

Signs and Symptoms of Exposure
To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

Synergistic effects
no data available

Additional Information
RTECS: Not available

12. ECOLOGICAL INFORMATION

Toxicity

no data available

Persistence and degradability
no data available

Bioaccumulative potential
no data available

Mobility in soil
no data available

PBT and vPvB assessment
no data available

Other adverse effects

no data available

13. DISPOSAL CONSIDERATIONS

Product
Offer surplus and non-recyclable solutions to a licensed disposal company. Contact a licensed professional waste disposal service to dispose of this material.

Contaminated packaging
Dispose of as unused product.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods

IMDG
Not dangerous goods

IATA
Not dangerous goods

15. REGULATORY INFORMATION

OSHA Hazards
Irritant

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
Acute Health Hazard

Massachusetts Right To Know Components
No components are subject to the Massachusetts Right to Know Act.

Pennsylvania Right To Know Components

	CAS-No.	Revision Date
Water	7732-18-5	
Poly(4-styrenesulfonic acid-co-maleic acid) sodium salt	68037-40-1	

New Jersey Right To Know Components

	CAS-No.	Revision Date
Water	7732-18-5	
Poly(4-styrenesulfonic acid-co-maleic acid) sodium salt	68037-40-1	

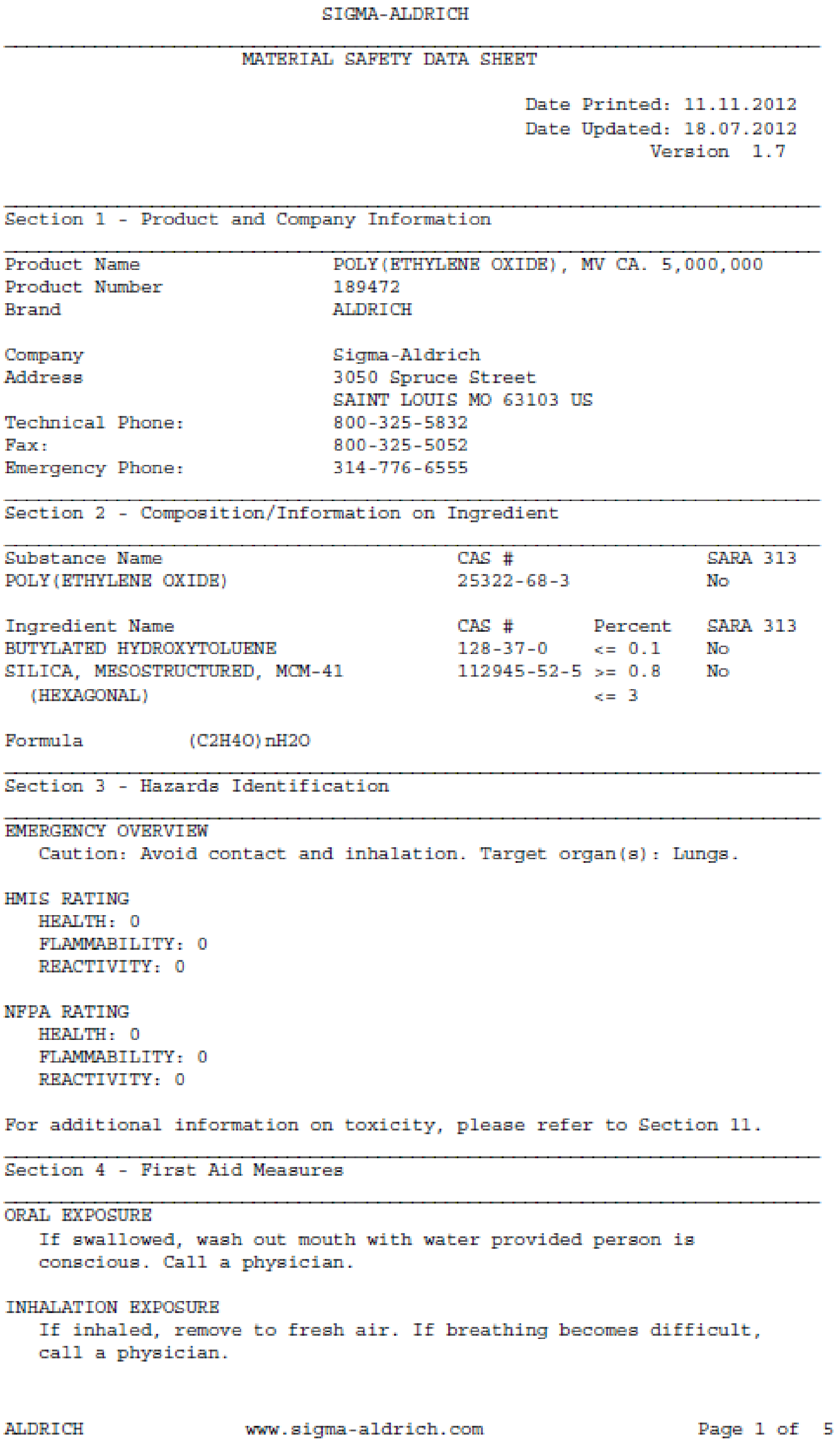
California Prop. 65 Components
This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

16. OTHER INFORMATION

Further information

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Co., shall not be held liable for any damage resulting from handling or from contact with the above product. See reverse side of invoice or packing slip for additional terms and conditions of sale.

Polyethylene Oxide



SIGMA-ALDRICH

MATERIAL SAFETY DATA SHEET

Date Printed: 11.11.2012
Date Updated: 18.07.2012
Version 1.7

Section 1 - Product and Company Information

Product Name	POLY(ETHYLENE OXIDE), MV CA. 5,000,000
Product Number	189472
Brand	ALDRICH
Company	Sigma-Aldrich
Address	3050 Spruce Street SAINT LOUIS MO 63103 US
Technical Phone:	800-325-5832
Fax:	800-325-5052
Emergency Phone:	314-776-6555

Section 2 - Composition/Information on Ingredient

Substance Name	CAS #		SARA 313
POLY(ETHYLENE OXIDE)	25322-68-3		No

Ingredient Name	CAS #	Percent	SARA 313
BUTYLATED HYDROXYTOLUENE	128-37-0	<= 0.1	No
SILICA, MESOSTRUCTURED, MCM-41 (HEXAGONAL)	112945-52-5	>= 0.8 <= 3	No

Formula (C2H4O)nH2O

Section 3 - Hazards Identification

EMERGENCY OVERVIEW
Caution: Avoid contact and inhalation. Target organ(s): Lungs.

HMIS RATING
HEALTH: 0
FLAMMABILITY: 0
REACTIVITY: 0

NFPA RATING
HEALTH: 0
FLAMMABILITY: 0
REACTIVITY: 0

For additional information on toxicity, please refer to Section 11.

Section 4 - First Aid Measures

ORAL EXPOSURE
If swallowed, wash out mouth with water provided person is conscious. Call a physician.

INHALATION EXPOSURE
If inhaled, remove to fresh air. If breathing becomes difficult, call a physician.

DERMAL EXPOSURE

In case of contact, immediately wash skin with soap and copious amounts of water.

EYE EXPOSURE

In case of contact with eyes, flush with copious amounts of water for at least 15 minutes. Assure adequate flushing by separating the eyelids with fingers. Call a physician.

Section 5 - Fire Fighting Measures

CONDITIONS OF FLAMMABILITY

Under fire conditions, material may decompose to form flammable and/or explosive mixtures in air.

FLASH POINT

N/A

AUTOIGNITION TEMP

N/A

FLAMMABILITY

N/A

EXTINGUISHING MEDIA

Suitable: Water spray. Carbon dioxide, dry chemical powder, or appropriate foam.

FIREFIGHTING

Protective Equipment: Wear self-contained breathing apparatus and protective clothing to prevent contact with skin and eyes.
Specific Hazard(s): Emits toxic fumes under fire conditions.

Section 6 - Accidental Release Measures

PROCEDURE(S) OF PERSONAL PRECAUTION(S)

Exercise appropriate precautions to minimize direct contact with skin or eyes and prevent inhalation of dust.

METHODS FOR CLEANING UP

Sweep up, place in a bag and hold for waste disposal. Avoid raising dust. Ventilate area and wash spill site after material pickup is complete.

Section 7 - Handling and Storage

HANDLING

User Exposure: Avoid inhalation. Avoid contact with eyes, skin, and clothing. Avoid prolonged or repeated exposure.

STORAGE

Suitable: Keep tightly closed.

Section 8 - Exposure Controls / PPE

ENGINEERING CONTROLS

Safety shower and eye bath. Mechanical exhaust required.

PERSONAL PROTECTIVE EQUIPMENT

Respiratory: Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU). Respiratory protection is not required. Where protection from nuisance levels of dusts are desired, use type N95 (US) or type P1 (EN 143) dust masks.
Hand: Protective gloves.
Eye: Chemical safety goggles.

GENERAL HYGIENE MEASURES

Wash thoroughly after handling.

Section 9 - Physical/Chemical Properties

Appearance — Physical State: Solid

Property	Value	At Temperature or Pressure
pH	N/A	
BP/BP Range	N/A	
MP/MP Range	N/A	
Freezing Point	N/A	
Vapor Pressure	N/A	
Vapor Density	N/A	
Saturated Vapor Conc.	N/A	
Bulk Density	N/A	
Odor Threshold	N/A	
Volatile%	N/A	
VOC Content	N/A	
Water Content	N/A	
Solvent Content	N/A	
Evaporation Rate	N/A	
Viscosity	N/A	
Surface Tension	N/A	
Partition Coefficient	N/A	
Decomposition Temp.	N/A	
Flash Point	N/A	
Explosion Limits	N/A	
Flammability	N/A	
Autoignition Temp	N/A	
Refractive Index	N/A	
Optical Rotation	N/A	
Miscellaneous Data	N/A	
Solubility	N/A	

N/A = not available

Section 10 - Stability and Reactivity

STABILITY

Stable: Stable.
Materials to Avoid: Strong oxidizing agents.

HAZARDOUS DECOMPOSITION PRODUCTS

Hazardous Decomposition Products: Carbon monoxide, Carbon dioxide, Silicon oxide.

HAZARDOUS POLYMERIZATION

Hazardous Polymerization: Will not occur

Section 11 - Toxicological Information

ROUTE OF EXPOSURE

Skin Contact: May cause skin irritation.
Skin Absorption: May be harmful if absorbed through the skin.
Eye Contact: May cause eye irritation.
Inhalation: Material may be irritating to mucous membranes and upper respiratory tract. May be harmful if inhaled.
Ingestion: May be harmful if swallowed.

TARGET ORGAN(S) OR SYSTEM(S)

Lungs.

SIGNS AND SYMPTOMS OF EXPOSURE

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

Section 12 - Ecological Information

No data available.

Section 13 - Disposal Considerations

APPROPRIATE METHOD OF DISPOSAL OF SUBSTANCE OR PREPARATION

Contact a licensed professional waste disposal service to dispose of this material. Dissolve or mix the material with a combustible solvent and burn in a chemical incinerator equipped with an afterburner and scrubber. Observe all federal, state, and local environmental regulations.

Section 14 - Transport Information

DOT

Proper Shipping Name: None
Non-Hazardous for Transport: This substance is considered to be non-hazardous for transport.

IATA

Non-Hazardous for Air Transport: Non-hazardous for air transport.

Section 15 - Regulatory Information

US CLASSIFICATION AND LABEL TEXT

US Statements: Caution: Avoid contact and inhalation. Target organ(s): Lungs.

UNITED STATES REGULATORY INFORMATION

SARA LISTED: No

CANADA REGULATORY INFORMATION

WHMIS Classification: This product has been classified in accordance with the hazard criteria of the CPR, and the MSDS contains all the information required by the CPR.
DSL: Yes
NDSL: No

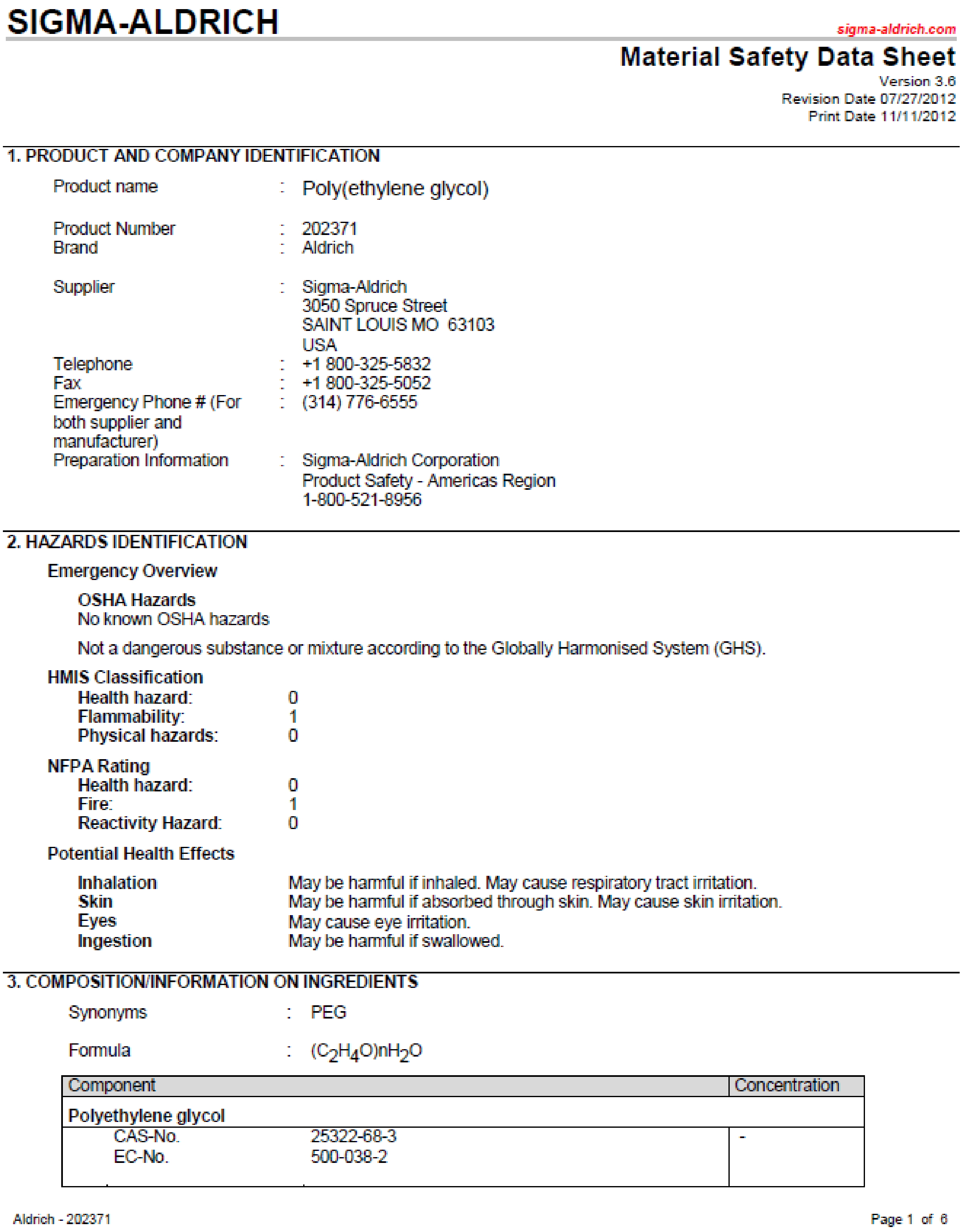
Section 16 - Other Information

DISCLAIMER

For R&D use only. Not for drug, household or other uses.

WARRANTY

Polyethylene Glycol



SIGMA-ALDRICH

sigma-aldrich.com

Material Safety Data Sheet

Version 3.6
Revision Date 07/27/2012
Print Date 11/11/2012

1. PRODUCT AND COMPANY IDENTIFICATION

Product name : Poly(ethylene glycol)

Product Number : 202371
Brand : Aldrich

Supplier : Sigma-Aldrich
3050 Spruce Street
SAINT LOUIS MO 63103
USA
Telephone : +1 800-325-5832
Fax : +1 800-325-5052
Emergency Phone # (For both supplier and manufacturer) : (314) 776-6555
Preparation Information : Sigma-Aldrich Corporation
Product Safety - Americas Region
1-800-521-8956

2. HAZARDS IDENTIFICATION

Emergency Overview

OSHA Hazards
No known OSHA hazards

Not a dangerous substance or mixture according to the Globally Harmonised System (GHS).

HMIS Classification
Health hazard: 0
Flammability: 1
Physical hazards: 0

NFPA Rating
Health hazard: 0
Fire: 1
Reactivity Hazard: 0

Potential Health Effects

Inhalation	May be harmful if inhaled. May cause respiratory tract irritation.
Skin	May be harmful if absorbed through skin. May cause skin irritation.
Eyes	May cause eye irritation.
Ingestion	May be harmful if swallowed.

3. COMPOSITION/INFORMATION ON INGREDIENTS

Synonyms : PEG

Formula : $(C_2H_4O)nH_2O$

Component		Concentration
Polyethylene glycol		
CAS-No.	25322-68-3	-
EC-No.	500-038-2	

4. FIRST AID MEASURES

If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration.

In case of skin contact
Wash off with soap and plenty of water.

In case of eye contact
Flush eyes with water as a precaution.

If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water.

5. FIREFIGHTING MEASURES

Conditions of flammability
Not flammable or combustible.

Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

Special protective equipment for firefighters
Wear self contained breathing apparatus for fire fighting if necessary.

Hazardous combustion products
Hazardous decomposition products formed under fire conditions. - Carbon oxides

6. ACCIDENTAL RELEASE MEASURES

Personal precautions
Avoid breathing vapors, mist or gas.

Environmental precautions
Do not let product enter drains.

Methods and materials for containment and cleaning up
Keep in suitable, closed containers for disposal.

7. HANDLING AND STORAGE

Conditions for safe storage
Keep container tightly closed in a dry and well-ventilated place.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Components with workplace control parameters

Components	CAS-No.	Value	Control parameters	Basis
Polyethylene glycol	25322-68-3	TWA	10 mg/m3	USA. Workplace Environmental Exposure Levels (WEEL)

Personal protective equipment

Respiratory protection
Respiratory protection not required. For nuisance exposures use type OV/AG (US) or type ABEK (EU EN 14387) respirator cartridges. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Hand protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Immersion protection
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm

Break through time: > 480 min
Material tested:Dermatril® (Aldrich Z677272, Size M)

Splash protection
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: > 30 min
Material tested:Dermatril® (Aldrich Z677272, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 873000, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an Industrial Hygienist familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

Eye protection
Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin and body protection
impervious clothing, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Hygiene measures
General industrial hygiene practice.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance

Form	viscous
Colour	no data available

Safety data

pH	6 - 7 at 10 g/l at 23 °C (73 °F)
Melting point/freezing point	Melting point/range: 15 °C (59 °F) - lit.
Boiling point	> 300 °C (> 572 °F) at 1.013 hPa (0.760 mmHg)
Flash point	220.00 °C (428.00 °F) - closed cup
Ignition temperature	no data available
Autoignition temperature	305 °C (581 °F)
Lower explosion limit	no data available
Upper explosion limit	no data available
Vapour pressure	< 0.01 hPa (< 0.01 mmHg) at 20 °C (68 °F)
Density	1.125 g/mL at 25 °C (77 °F)
Water solubility	soluble
Partition coefficient: n-octanol/water	no data available
Solubility in other solvents	Alcohol - soluble
	Hydrocarbons - soluble
Viscosity, kinematic	75 - 95 mm2/s at 20 °C (68 °F)
Relative vapour density	no data available

Odour	no data available
Odour Threshold	no data available
Evaporation rate	no data available

10. STABILITY AND REACTIVITY

Chemical stability
Stable under recommended storage conditions.

Possibility of hazardous reactions
no data available

Conditions to avoid
no data available

Materials to avoid
Strong oxidizing agents

Hazardous decomposition products
Hazardous decomposition products formed under fire conditions. - Carbon oxides
Other decomposition products - no data available

11. TOXICOLOGICAL INFORMATION

Acute toxicity

Oral LD50
LD50 Oral - rat - 27,500 mg/kg
Remarks: Kidney, Ureter, Bladder:Other changes.

Inhalation LC50
no data available

Dermal LD50
LD50 Dermal - rabbit - > 20,000 mg/kg

Other information on acute toxicity
no data available

Skin corrosion/irritation
Serious eye damage/eye irritation
Eyes - rabbit - Mild eye irritation - Draize Test

Respiratory or skin sensitization
no data available

Germ cell mutagenicity
no data available

Carcinogenicity

IARC:	No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.
ACGIH:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.
NTP:	No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.
OSHA:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

no data available

Teratogenicity

no data available

Specific target organ toxicity - single exposure (Globally Harmonized System)
no data available

Specific target organ toxicity - repeated exposure (Globally Harmonized System)
no data available

Aspiration hazard
no data available

Potential health effects

Inhalation	May be harmful if inhaled. May cause respiratory tract irritation.
Ingestion	May be harmful if swallowed.
Skin	May be harmful if absorbed through skin. May cause skin irritation.
Eyes	May cause eye irritation.

Signs and Symptoms of Exposure
To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

Synergistic effects
no data available

Additional Information
RTECS: TQ3630000

12. ECOLOGICAL INFORMATION

Toxicity

Toxicity to fish	LC50 - Leuciscus idus (Golden orfe) - < 500 mg/l Remarks: no data available

Persistence and degradability

Biodegradability	aerobic Result: > 90 % - Readily biodegradable.

Bioaccumulative potential
no data available

Mobility in soil
no data available

PBT and vPvB assessment
no data available

Other adverse effects

Biochemical Oxygen Demand (BOD)	< 10 mg/g 1,120 mg/g
Chemical Oxygen Demand (COD)	1,660 mg/g
Additional ecological information	no data available

13. DISPOSAL CONSIDERATIONS

Product
Offer surplus and non-recyclable solutions to a licensed disposal company.

Contaminated packaging
Dispose of as unused product.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods

IMDG
Not dangerous goods

IATA
Not dangerous goods

15. REGULATORY INFORMATION

OSHA Hazards
No known OSHA hazards

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
No SARA Hazards

Massachusetts Right To Know Components
No components are subject to the Massachusetts Right to Know Act.

Pennsylvania Right To Know Components

	CAS-No.	Revision Date
Polyethylene glycol	25322-68-3	

New Jersey Right To Know Components

	CAS-No.	Revision Date
Polyethylene glycol	25322-68-3	

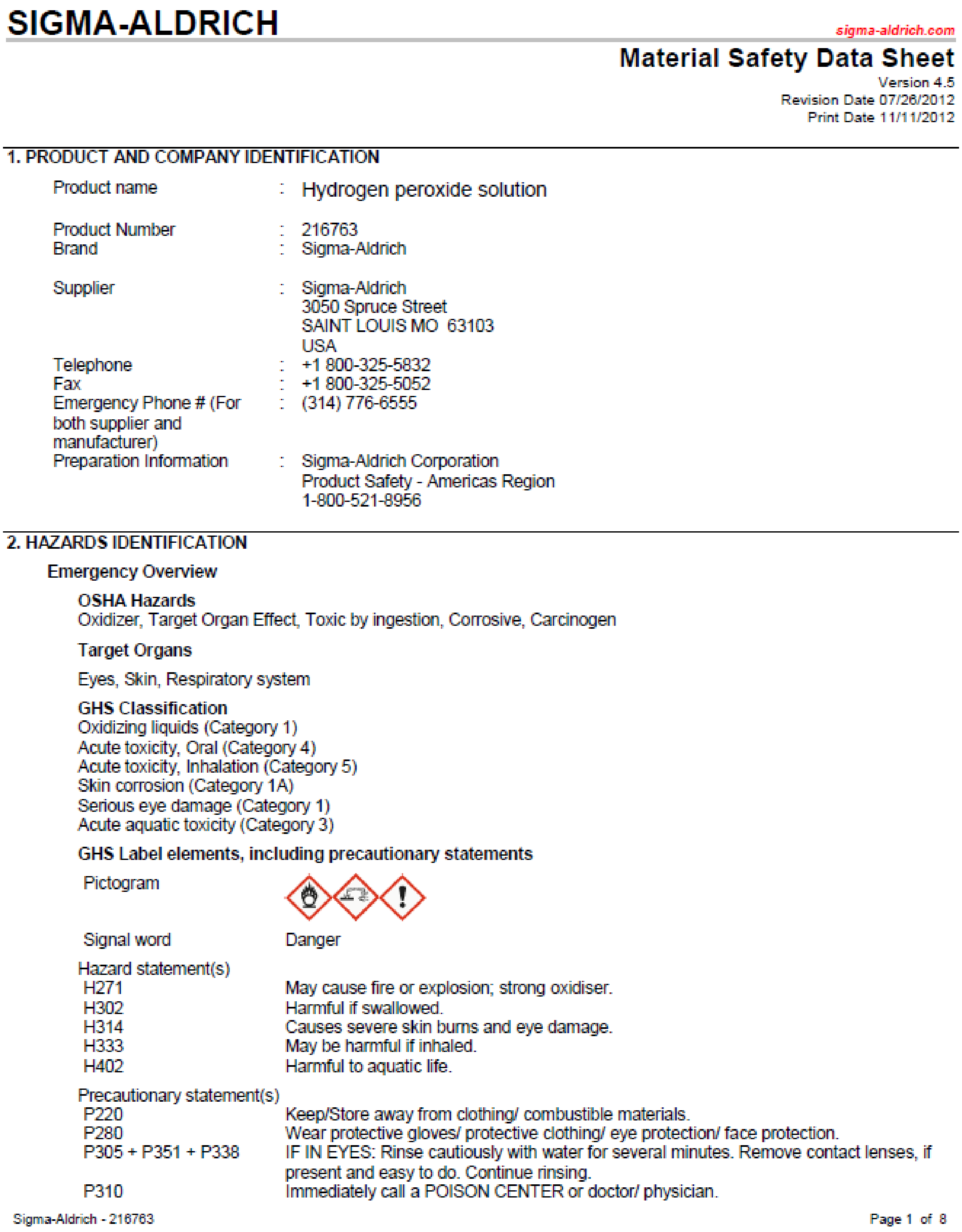
California Prop. 65 Components
This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

16. OTHER INFORMATION

Further information

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

Hydrogen Peroxide



SIGMA-ALDRICH

sigma-aldrich.com

Material Safety Data Sheet

Version 4.5
Revision Date 07/26/2012
Print Date 11/11/2012

1. PRODUCT AND COMPANY IDENTIFICATION

Product name	:	Hydrogen peroxide solution
Product Number	:	216763
Brand	:	Sigma-Aldrich
Supplier	:	Sigma-Aldrich 3050 Spruce Street SAINT LOUIS MO 63103 USA
Telephone	:	+1 800-325-5832
Fax	:	+1 800-325-5052
Emergency Phone # (For both supplier and manufacturer)	:	(314) 776-6555
Preparation Information	:	Sigma-Aldrich Corporation Product Safety - Americas Region 1-800-521-8956

2. HAZARDS IDENTIFICATION

Emergency Overview

OSHA Hazards
Oxidizer, Target Organ Effect, Toxic by ingestion, Corrosive, Carcinogen

Target Organs

Eyes, Skin, Respiratory system

GHS Classification
Oxidizing liquids (Category 1)
Acute toxicity, Oral (Category 4)
Acute toxicity, Inhalation (Category 5)
Skin corrosion (Category 1A)
Serious eye damage (Category 1)
Acute aquatic toxicity (Category 3)

GHS Label elements, including precautionary statements

Pictogram	
Signal word	Danger

Hazard statement(s)

H271	May cause fire or explosion; strong oxidiser.
H302	Harmful if swallowed.
H314	Causes severe skin burns and eye damage.
H333	May be harmful if inhaled.
H402	Harmful to aquatic life.

Precautionary statement(s)

P220	Keep/Store away from clothing/ combustible materials.
P280	Wear protective gloves/ protective clothing/ eye protection/ face protection.
P305 + P351 + P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P310	Immediately call a POISON CENTER or doctor/ physician.

HMIS Classification

Health hazard:	3
Chronic Health Hazard:	*
Flammability:	0
Physical hazards:	2

NFPA Rating

Health hazard:	3
Fire:	0
Reactivity Hazard:	2
Special hazard.:	OX

Potential Health Effects

Inhalation	May be harmful if inhaled. Material is extremely destructive to the tissue of the mucous membranes and upper respiratory tract.
Skin	May be harmful if absorbed through skin. Causes skin burns.
Eyes	Causes eye burns.
Ingestion	Toxic if swallowed.

3. COMPOSITION/INFORMATION ON INGREDIENTS

Formula : H_2O_2

Molecular Weight : 34.01 g/mol

Component		Classification	Concentration
Hydrogen peroxide			
CAS-No. EC-No. Index-No.	7722-84-1 231-765-0 008-003-00-9	Ox. Liq. 1; Acute Tox. 4; Skin Corr. 1A; H271, H302 + H332, H314	30 - 60 %

For the full text of the H-Statements and R-Phrases mentioned in this Section, see Section 16

4. FIRST AID MEASURES

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance.Move out of dangerous area.

If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

In case of skin contact
Take off contaminated clothing and shoes immediately. Wash off with soap and plenty of water. Consult a physician.

In case of eye contact
Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician.Continue rinsing eyes during transport to hospital.

If swallowed
Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

5. FIREFIGHTING MEASURES

Conditions of flammability
Not flammable or combustible.

Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

Special protective equipment for firefighters
Wear self contained breathing apparatus for fire fighting if necessary.

Hazardous combustion products

Hazardous decomposition products formed under fire conditions. - Nature of decomposition products not known.

Further information

Use water spray to cool unopened containers.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions

Use personal protective equipment. Avoid breathing vapors, mist or gas. Ensure adequate ventilation. Evacuate personnel to safe areas.

Environmental precautions

Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

Methods and materials for containment and cleaning up

Contain spillage, and then collect with an electrically protected vacuum cleaner or by wet-brushing and place in container for disposal according to local regulations (see section 13).

7. HANDLING AND STORAGE

Precautions for safe handling

Avoid contact with skin and eyes. Avoid inhalation of vapour or mist.
Keep away from sources of ignition - No smoking.

Conditions for safe storage

Keep container tightly closed in a dry and well-ventilated place. Containers which are opened must be carefully resealed and kept upright to prevent leakage.

Recommended storage temperature: 2 - 8 °C

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Components with workplace control parameters

Components	CAS-No.	Value	Control parameters	Basis
Hydrogen peroxide	7722-84-1	TWA	1 ppm	USA. ACGIH Threshold Limit Values (TLV)
Remarks	Eye, skin, & Upper Respiratory Tract irritation Confirmed animal carcinogen with unknown relevance to humans			
		TWA	1 ppm 1.4 mg/m3	USA. NIOSH Recommended Exposure Limits
		TWA	1 ppm 1.4 mg/m3	USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants
	The value in mg/m3 is approximate.			
		TWA	1 ppm 1.4 mg/m3	USA. OSHA - TABLE Z-1 Limits for Air Contaminants - 1910.1000

Personal protective equipment

Respiratory protection

Where risk assessment shows air-purifying respirators are appropriate use a full-face respirator with multi-purpose combination (US) or type ABEK (EN 14387) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Hand protection

Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Immersion protection
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (Aldrich Z677272, Size M)

Splash protection
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (Aldrich Z677272, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 873000, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an Industrial Hygienist familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

Eye protection
Tightly fitting safety goggles. Faceshield (8-inch minimum). Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin and body protection
Complete suit protecting against chemicals, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Hygiene measures
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance

Form	liquid, clear
Colour	colourless

Safety data

pH	no data available
Melting point/freezing point	no data available
Boiling point	no data available
Flash point	not applicable
Ignition temperature	no data available
Autoignition temperature	no data available
Lower explosion limit	no data available
Upper explosion limit	no data available
Vapour pressure	no data available
Density	1.110 g/cm3
Water solubility	no data available
Partition coefficient: n-octanol/water	no data available
Relative vapour density	no data available
Odour	no data available

Odour Threshold	no data available
Evaporation rate	no data available

10. STABILITY AND REACTIVITY

Chemical stability
Stable under recommended storage conditions.

Possibility of hazardous reactions
no data available

Conditions to avoid
no data available

Materials to avoid
Zinc, Powdered metals, Iron, Copper, Nickel, Brass, Iron and iron salts.

Hazardous decomposition products
Hazardous decomposition products formed under fire conditions. - Nature of decomposition products not known.
Other decomposition products - no data available

Contains the following stabiliser(s):
Proprietary Inhibitor (<0.1 %)

11. TOXICOLOGICAL INFORMATION

Acute toxicity

Oral LD50
no data available

Inhalation LC50
no data available

Dermal LD50
no data available

Other information on acute toxicity
no data available

Skin corrosion/irritation
no data available

Serious eye damage/eye irritation
Eyes: no data available

Respiratory or skin sensitization
no data available

Germ cell mutagenicity

no data available

Carcinogenicity

IARC:	3 - Group 3: Not classifiable as to its carcinogenicity to humans (Hydrogen peroxide)
NTP:	No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.
OSHA:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

no data available

Teratogenicity

no data available

Specific target organ toxicity - single exposure (Globally Harmonized System)
no data available

Specific target organ toxicity - repeated exposure (Globally Harmonized System)
no data available

Aspiration hazard
no data available

Potential health effects

Inhalation	May be harmful if inhaled. Material is extremely destructive to the tissue of the mucous membranes and upper respiratory tract.
Ingestion	Toxic if swallowed.
Skin	May be harmful if absorbed through skin. Causes skin burns.
Eyes	Causes eye burns.

Signs and Symptoms of Exposure
To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

Synergistic effects
no data available

Additional Information
RTECS: Not available

12. ECOLOGICAL INFORMATION

Toxicity

no data available

Persistence and degradability
no data available

Bioaccumulative potential
no data available

Mobility in soil
no data available

PBT and vPvB assessment
no data available

Other adverse effects

An environmental hazard cannot be excluded in the event of unprofessional handling or disposal.

Harmful to aquatic life.

13. DISPOSAL CONSIDERATIONS

Product
Burn in a chemical incinerator equipped with an afterburner and scrubber but exert extra care in igniting as this material is highly flammable. Offer surplus and non-recyclable solutions to a licensed disposal company. Contact a licensed professional waste disposal service to dispose of this material. Dissolve or mix the material with a combustible solvent and burn in a chemical incinerator equipped with an afterburner and scrubber.

Contaminated packaging
Dispose of as unused product.

14. TRANSPORT INFORMATION

DOT (US)

UN number: 2014 Class: 5.1 (8) Packing group: II
Proper shipping name: Hydrogen peroxide, aqueous solutions
Reportable Quantity (RQ):
Marine pollutant: No
Poison Inhalation Hazard: No

IMDG
UN number: 2014 Class: 5.1 (8) Packing group: II EMS-No: F-H, S-Q
Proper shipping name: HYDROGEN PEROXIDE, AQUEOUS SOLUTION
Marine pollutant: No

IATA
UN number: 2014 Class: 5.1 (8) Packing group: II
Proper shipping name: Hydrogen peroxide, aqueous solution

15. REGULATORY INFORMATION

OSHA Hazards
Oxidizer, Target Organ Effect, Toxic by ingestion, Corrosive, Carcinogen

SARA 302 Components
The following components are subject to reporting levels established by SARA Title III, Section 302:

	CAS-No.	Revision Date
Hydrogen peroxide	7722-84-1	1993-04-24

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
Reactivity Hazard, Acute Health Hazard, Chronic Health Hazard

Massachusetts Right To Know Components

	CAS-No.	Revision Date
Hydrogen peroxide	7722-84-1	1993-04-24

Pennsylvania Right To Know Components

	CAS-No.	Revision Date
Water	7732-18-5	
Hydrogen peroxide	7722-84-1	1993-04-24

New Jersey Right To Know Components

	CAS-No.	Revision Date
Water	7732-18-5	
Hydrogen peroxide	7722-84-1	1993-04-24

California Prop. 65 Components
This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

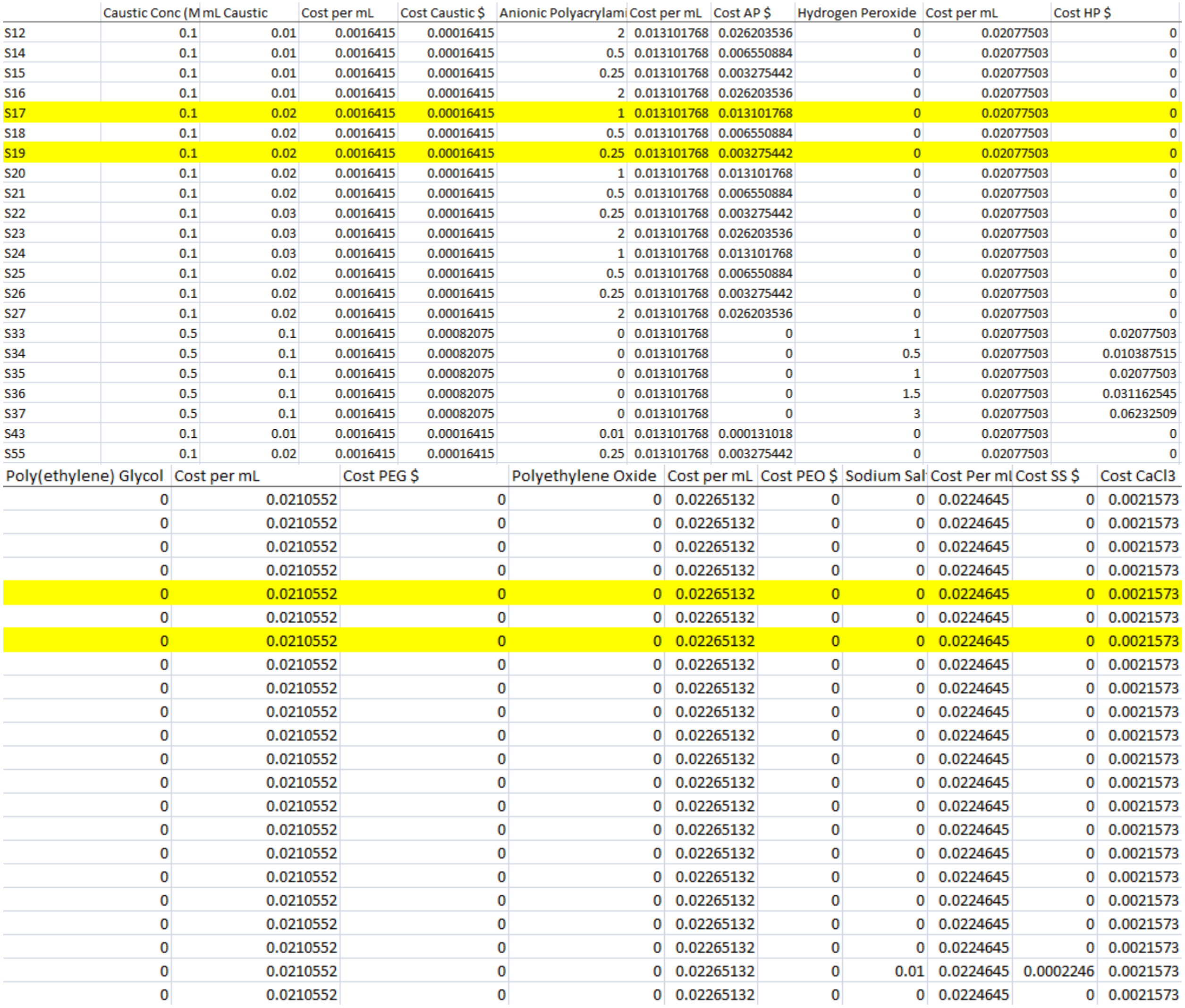
16. OTHER INFORMATION

Text of H-code(s) and R-phrase(s) mentioned in Section 3

Acute Tox.	Acute toxicity
H271	May cause fire or explosion; strong oxidiser.
H302 + H332	Harmful if swallowed or if inhaled
H314	Causes severe skin burns and eye damage.
Ox. Liq.	Oxidizing liquids
Skin Corr.	Skin corrosion

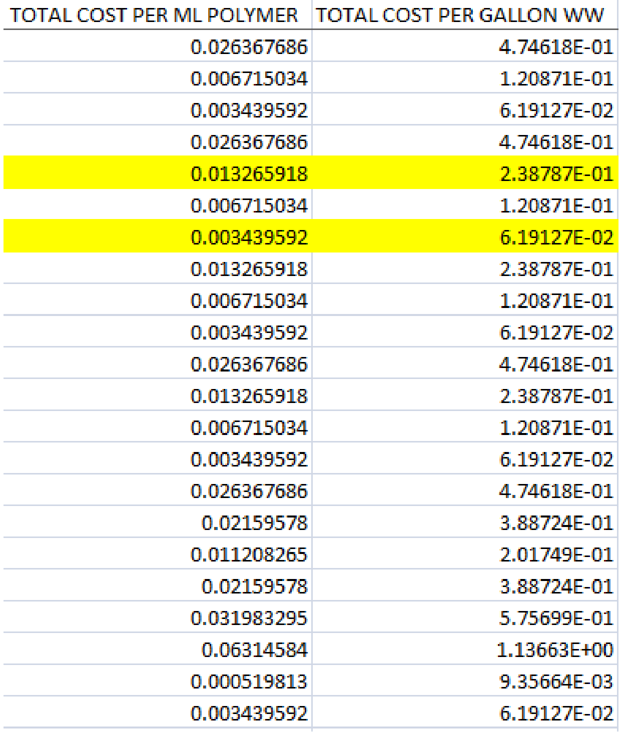
Further information

Appendix D: Cost Analysis Sheet



	Caustic Conc (M	mL Caustic	Cost per mL	Cost Caustic $	Anionic Polyacrylami	Cost per mL	Cost AP $	Hydrogen Peroxide	Cost per mL	Cost HP $
S12	0.1	0.01	0.0016415	0.00016415	2	0.013101768	0.026203536	0	0.02077503	0
S14	0.1	0.01	0.0016415	0.00016415	0.5	0.013101768	0.006550884	0	0.02077503	0
S15	0.1	0.01	0.0016415	0.00016415	0.25	0.013101768	0.003275442	0	0.02077503	0
S16	0.1	0.01	0.0016415	0.00016415	2	0.013101768	0.026203536	0	0.02077503	0
S17	0.1	0.02	0.0016415	0.00016415	1	0.013101768	0.013101768	0	0.02077503	0
S18	0.1	0.02	0.0016415	0.00016415	0.5	0.013101768	0.006550884	0	0.02077503	0
S19	0.1	0.02	0.0016415	0.00016415	0.25	0.013101768	0.003275442	0	0.02077503	0
S20	0.1	0.02	0.0016415	0.00016415	1	0.013101768	0.013101768	0	0.02077503	0
S21	0.1	0.02	0.0016415	0.00016415	0.5	0.013101768	0.006550884	0	0.02077503	0
S22	0.1	0.03	0.0016415	0.00016415	0.25	0.013101768	0.003275442	0	0.02077503	0
S23	0.1	0.03	0.0016415	0.00016415	2	0.013101768	0.026203536	0	0.02077503	0
S24	0.1	0.03	0.0016415	0.00016415	1	0.013101768	0.013101768	0	0.02077503	0
S25	0.1	0.02	0.0016415	0.00016415	0.5	0.013101768	0.006550884	0	0.02077503	0
S26	0.1	0.02	0.0016415	0.00016415	0.25	0.013101768	0.003275442	0	0.02077503	0
S27	0.1	0.02	0.0016415	0.00016415	2	0.013101768	0.026203536	0	0.02077503	0
S33	0.5	0.1	0.0016415	0.00082075	0	0.013101768	0	1	0.02077503	0.02077503
S34	0.5	0.1	0.0016415	0.00082075	0	0.013101768	0	0.5	0.02077503	0.010387515
S35	0.5	0.1	0.0016415	0.00082075	0	0.013101768	0	1	0.02077503	0.02077503
S36	0.5	0.1	0.0016415	0.00082075	0	0.013101768	0	1.5	0.02077503	0.031162545
S37	0.5	0.1	0.0016415	0.00082075	0	0.013101768	0	3	0.02077503	0.06232509
S43	0.1	0.01	0.0016415	0.00016415	0.01	0.013101768	0.000131018	0	0.02077503	0
S55	0.1	0.02	0.0016415	0.00016415	0.25	0.013101768	0.003275442	0	0.02077503	0

Poly(ethylene) Glycol	Cost per mL	Cost PEG $	Polyethylene Oxide	Cost per mL	Cost PEO $	Sodium Sal	Cost Per ml	Cost SS $	Cost CaCl3
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573
0	0.0210552	0	0	0.02265132	0	0.01	0.0224645	0.0002246	0.0021573
0	0.0210552	0	0	0.02265132	0	0	0.0224645	0	0.0021573



TOTAL COST PER ML POLYMER	TOTAL COST PER GALLON WW
0.026367686	4.74618E-01
0.006715034	1.20871E-01
0.003439592	6.19127E-02
0.026367686	4.74618E-01
0.013265918	2.38787E-01
0.006715034	1.20871E-01
0.003439592	6.19127E-02
0.013265918	2.38787E-01
0.006715034	1.20871E-01
0.003439592	6.19127E-02
0.026367686	4.74618E-01
0.013265918	2.38787E-01
0.006715034	1.20871E-01
0.003439592	6.19127E-02
0.026367686	4.74618E-01
0.02159578	3.88724E-01
0.011208265	2.01749E-01
0.02159578	3.88724E-01
0.031983295	5.75699E-01
0.06314584	1.13663E+00
0.000519813	9.35664E-03
0.003439592	6.19127E-02