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Dissolution of Chromium from Inhalable Primer Paint Particles into a Simulated Lung Fluid

David A. Kauth

DISSOLUTION OF CHROMIUM FROM INHALABLE PRIMER PAINT PARTICLES INTO A SIMULATED LUNG FLUID

THESIS

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AFIT/GEE/ENV/01M-07

DEPARTMENT OF THE AIR FORCE
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THESIS

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Abstract

The use of chromate as a corrosion inhibitor in primer paint is an essential component for the protection of aluminum-skinned aircraft and the primary source of hexavalent chromium (Cr (VI)) exposure to USAF aircraft painters. The objective of this research was to quantify the dissolution of chromate from freshly sprayed paint particles into a simulated lung fluid (SLF). Two primer paints were sprayed with a paint spray gun to generate overspray particles for collection into impingers filled with SLF. Particles were allowed to soak in SLF for 24 and 48 hours and then the particles were removed by centrifugation. The remaining Cr (VI) dissolved in the SLF was then compared to the initial Cr (VI) concentration with particles. The results indicate that the dissolution of Cr (VI) into SLF is hindered by the paint. Also, the results indicate that the amount of Cr (VI) dissolved into SLF from the paint particles is not significantly different between the two paints tested or between the 24- and 48-hour resident times. This study suggests that Cr (VI) in paint particles is less bioavailable than Cr (VI) in other particles such as dust or mist.

DISSOLUTION OF CHROMIUM FROM INHALABLE PRIMER PAINT PARTICLES INTO A SIMULATED LUNG FLUID

I. Introduction

Air Force Primer Paint Overview

Coating systems—comprising a metal-surface treatment, a primer and a topcoat—are used extensively throughout the United States Air Force (USAF) to protect metal surfaces of aircraft from the hostile environment to which they are exposed on a daily basis. Primers are paints and/or coatings that provide corrosion resistance to a metal surface and promote adhesion between the surface and the topcoat. Typical USAF primers contain passivating corrosion-inhibitive ingredients such as zinc chromate, barium chromate, and strontium chromate ($SrCrO_4$).

There are three military specifications (MIL-P-23377G, MIL-P-85582B, and MIL-P-87112) and one federal specification (TT-P-2760A) that regulate primer paint applied to USAF aircraft. The specifications identify $SrCrO_4$ and barium chromate as corrosion inhibitors. The use of $SrCrO_4$ as a corrosion inhibitor in primer paint is presently considered the primary source of hexavalent chromium (Cr (VI)) exposure to USAF aircraft painters.

Chromium Health Hazards

In the past several years, a number of agencies have reviewed the epidemiological and toxicological evidence and have classified hexavalent chromate (Cr (VI)) as a human carcinogen. For example, the Agency for Toxic Substances and Disease Registry

(ATSDR, 1990), the National Institute for Occupational Safety and Health (NIOSH, 1997), the International Agency for Research on Cancer (IARC, 1990), American Conference of Governmental Industrial Hygienists (ACGIH, 1998), and the Occupational Health and Safety Administration (OSHA, 1996) have classified Cr (VI) as a human carcinogen. Mancuso (1975) provides limited but adequate information demonstrating that Cr (VI) is a potential human carcinogen. Mancuso's data were used as a primary database for estimating the carcinogenic potency of Cr (VI). Three foreign studies on ferrochromium plants were also considered for use in the potency calculations (IRIS,1998).

Cr (VI) is the oxidative state of greater concern with occupational exposures. Occupational exposures to Cr (VI) can include welding, leather tanning, electroplating, textile manufacturing, photoengraving, copier servicing and exposures to paints/pigments (ATSDR 1990:2,3; IARC, 1990:24). Numerous detailed studies for Cr (VI) exposure have been conducted in the following manufacturing and industrial application areas: production of ferrochromium steel and high chromium alloy, production of chromates and chromate pigments, leather tanning, chromium plating and welding. Unfortunately, no health studies have been conducted for spray paint operations (IARC, 1990: 85–98). It is therefore not certain that workers exposed to Cr (VI) in painting operations experience the same health effects.

Occupational Exposure Concerns

The current OSHA limit of 100 $\mu g/m^3$ is a ceiling limit, which means that the air concentration can never exceed this concentration. OSHA's permissible exposure limit (PEL) for Cr (VI) is unchanged since 1971 (Martonik, 1995). In July 1993, OSHA was petitioned for an emergency temporary standard (ETS) to reduce the (PEL) for occupational exposures to Cr (VI).

OSHA's goal is to protect the occupational worker from hazardous materials but must include feasibility when determining exposure control in industry. The Oil, Chemical, and Atomic Workers International Union (OCAW) and Public Citizen's Health Research Group (HRG) petitioned OSHA to promulgate an ETS to reduce the PEL for Cr (VI) compounds to 0.5 $\mu g/m^3$ as an eight-hour, time-weighted average (TWA) (OSHA, 1996). OSHA has denied the ETS request but a rulemaking procedure has been initiated and a proposed rule is under investigation (OSHA, 1996).

Virtually all the studies that OSHA used to determine Cr (VI) carcinogenicity are based on Cr (VI) exposures in dust or chromic acid mist particles. There are virtually no studies involving Cr (VI) in primer paints. This thesis effort was undertaken to test the hypothesis that the bioavailability of Cr (VI) from exposure to paint particles is lower than that of such mists and dusts, because the resin–coated Cr (VI) present in the paint particle may suppress dissolution of Cr (VI) into body fluids. To accurately assess the need for a revised Cr (VI) exposure limit for paint particles, it is necessary to determine if the Cr (VI) will remain sequestered in the paint particle until it is removed from the body.

Thesis Objective

This research will quantify the dissolution of Cr (VI) from paint particles into a simulated lung fluid (SLF). Primer paint, aerosolized with a high-volume low-pressure (HVLP) paint spray gun, will be collected in the SLF by bubbling air through the SLF to transfer paint particles into the fluid. The SLF sample will be divided into three aliquots. If the statistical results indicate that dissociation of Cr (VI) is hindered when bound in paint, chromate-containing primer paints may not present as great a hazard as the types of exposure studied by OSHA to lower the exposure standard. In other words, if Cr (VI) in the primer paint does not dissociate as readily as free Cr (VI) compounds such as in acid droplets or dust particles, then significantly smaller quantities of Cr (VI) will be released into the lung fluid. Any Cr (VI) that does not dissociate from the particles will be cleared from the lungs before causing any damage to lung cell DNA.

Research Goals

This research study focuses on three primary research goals. The first goal is to develop a method for measuring the amount of metal dissociation from primer paint particles into SLF. A second goal is to determine to what extent the residence time of primer paint particles in SLF will affect the amount of Cr (VI) dissolving into the SLF. Contact time between the paint particles and the SLF may affect the curing process of the paint particle, causing a time-dependent increase in the extent of Cr (VI) dissolution. To determine whether time had an influence on dissolution, paint particles collected under a standardized set of conditions were allowed to soak in the SLF for 24 or for 48 hours. The fraction of Cr (VI) dissolved into the SLF at the 24 and 48-hour residence times are compared for differences. The final objective of this thesis is to quantify the fraction that dissociates into the SLF from the collected primer paint particles. The total concentration will be compared to the quantity and size of paint particles collected during spray painting.

II. Literature Review

Background

Protecting aircraft surfaces is vital to maintaining USAF aircraft integrity. Inadequate control and prevention of aircraft corrosion can shorten the service lifetime of the aircraft, hinder the USAF mission, and potentially compromise safety. The primary protection for the aircraft skin is the coating system. The performance of the paint coating is critical to preserve the passivated aluminum surface, which extends the life and performance of military aircraft. The primer paint serves two purposes. The first purpose is to provide a better surface to which the polyurethane topcoat adheres. The second purpose is to protect the metal skin from excessive corrosion by maintaining the mixed aluminum–chromium surface layer that prevents oxidation (TO 1-1-8, 1989:1-1). The component added to most primer paint that is responsible for corrosion control is $SrCrO_4$.

Chromium

Chromium is found naturally in the earth's crust. Chromium is both an essential micronutrient and a chemical carcinogen. Chromium exists in a series of oxidation states from –2 to +6; the most important stable states are elemental metal (Cr), trivalent (Cr (III)), and Cr (VI). Bioavailability and systemic distribution of chromium are influenced by the oxidation state and solubility (Ballantyne: 1995:25). The health effects of chromium are at least partially related to the valence state of the metal at the time of exposure. Cr (III) and Cr (VI) compounds are thought to be the most biologically significant (ATSDR, 1990:2). Chromium is both an essential micronutrient [as Cr (III)] and a chemical carcinogen [as Cr (VI)]. The biochemical importance of Cr (III) in glucose metabolism was reported more than a quarter century ago (Schwartz, 1959:2). On the other hand, the carcinogenicity of Cr (VI) compounds is well-documented (Schechtman, 1986:1; Persson, 1986; Adachi, 1986; Korallus, 1986; Levy, 1986; IARC, 1990:214).

There are many health hazards associated with Cr (VI). Cr (VI) compounds are oxidizing agents that can induce tissue damage directly. Cr (VI) increases cancer risk by the formation of DNA adducts, radical adducts, DNA cross-links and DNA strand breakage which interferes with normal DNA template replication and transcription (Dartsch, 1998: S40-41).

The principal industrial uses of Cr (VI) are as a structural element and as an anticorrosive. Large quantities are used to make stainless steel and to "chrome plate" regular steel. In both cases, Cr (VI) protects the iron in steel from corrosion. The principal industrial consumers of chromium are the metallurgical, refractory, and chemical industries. Cr (VI) is used in electroplating, welding, painting, and printing (Federal Register, 1996: 61: 62748-62788).

$SrCrO_4$ is a critical component in aircraft primer paint. If the metal surface of the aircraft skin cracks, chromate from the paint migrates into the crack. The release of the chromate ion restores the passivation of the aircraft surface and prevents corrosion.

$SrCrO_4$ is a yellow crystalline powder with a solubility of 1,200 ppm at 15 °C in water (Weast, 1985: B-147) but $SrCrO_4$ becomes more soluble in hydrochloric acid, nitric acid, acetic acid and ammonium salts (IARC, 1990:58,77). Common "synonyms" are *chromic acid* and *strontium salt*. $SrCrO_4$ was originally used as color in artists' paints but later found more-extensive use to impart corrosion resistance to aluminum, steel and magnesium alloys (IARC, 1990:58,77).

USAF Primer Paint

Of the three military specifications and one federal specification that provide performance requirements for primer paint applied to USAF aircraft, the most predominantly used primer paint for USAF aircraft is the military specification MIL-P-23377G (Weissling, 1996:61).

The MIL-P-23377G paint used in this thesis effort is a two-component, chemically cured, epoxy–polyamide primer paint. The two components are a base and a catalyst. The base and catalyst are mixed in a ratio of three parts base to one part catalyst prior to being applied. Primer paints from two manufacturers, Deft and DeSoto, were selected for this research. According to the manufacturers' Material Safety Data Sheets (MSDSs), which are found in Appendix A-1 and A-2 respectively, the Deft primer base component contains 25% (by weight) $SrCrO_4$ and the DeSoto primer base component contains 20% (by weight) $SrCrO_4$.

Regulatory Exposure Limits

The administrative procedures utilized by OSHA to promulgate a revised standard include a review of all available information. A literature review, done by OSHA, is performed to collect and consider all available research, data and reports germane to determination of the Cr (VI) standard. Also, research sponsored by OSHA and unsolicited research and reports are submitted to OSHA. The collected reports are numbered and filed into a legal file called a *docket*. The docket established for the revised chromium standard contains in excess of 300 individual studies (OSHA, 1999). No references citing Cr (VI) hazards associated with occupational use of paints or primers containing $SrCrO_4$ are in the Cr (VI) standard docket.

Alternatives to Chromated Primer Paints

The health concerns associated with Cr (VI) have led the USAF to search for alternatives. Boeing Company Aircraft and Missiles (B-A&M) have researched possible substitutes for chromate-containing primer paints for corrosion control. One Boeing report identified likely candidates to replace chromate containing primer paints. A subsequent report evaluated those candidates and narrowed the choices to be applied to operational aircraft for further evaluation. Successful results might provide the USAF with competent alternatives to chromated primer paint. One of the paints tested passed all tests, but it was inferior to primer paint containing chromate (NDCEE 1 & 2, 1998:1,1).

Interest in Cr (VI) compounds and products that contain them stems from the fact that workers have an increased risk of lung cancer due to the handling, processing, and application of chromate-containing compounds (Grogan, 1954:152). In the early 1930s, commercial development of chromates led to the widespread use of chromate pigments as metal-protective primers, especially on aircraft (Calupski, 1956:357-384). As of 1999, Cr (VI) is listed as the 16^{th} most hazardous substance in the Top 20 Hazardous Substances on the ATSDR/EPA Priority List of Hazardous Substances (ATSDR, 1999).

Inhalation Toxicology/Lung Model Physiology

There are four primary routes of exposure to toxic substances: inhalation, ingestion, dermal absorption and skin contact. From the standpoint of deposition of aerosolized paint particles, inhalation route of exposure is the most significant route of exposure and it will be addressed in this research.

The respiratory system can be divided into two main regions. These two regions are the conducting zone—consisting of the nasal passages or mouth, pharynx and larynx, trachea, bronchi, and bronchioles—and the respiratory zone, which consists of respiratory bronchioles, alveolar sacs and alveoli as illustrated below (Fox, 1996:460-1).

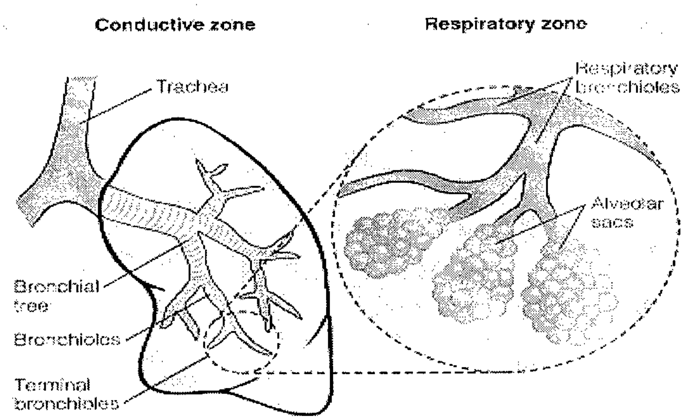


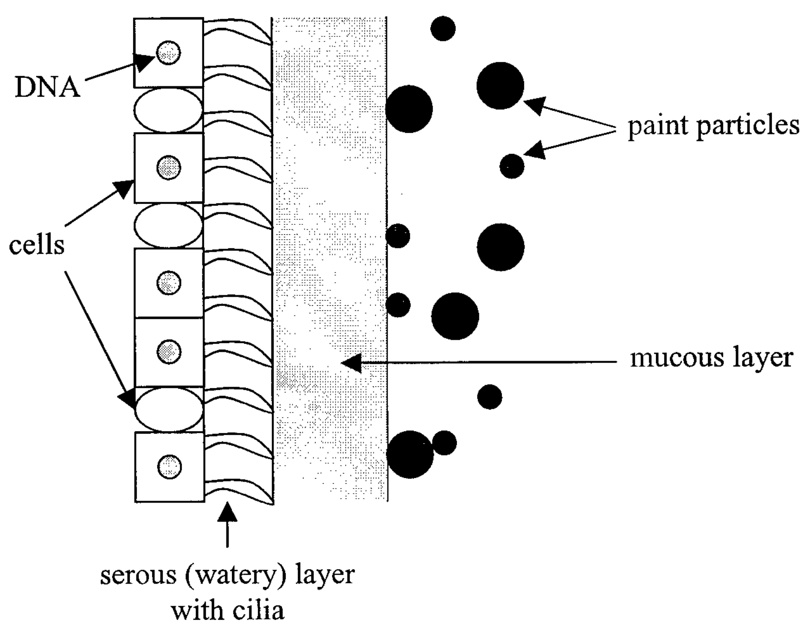
Figure 1. Conducting and Respiratory Zones

The Conducting Zone.

Within the conducting zone, air first travels through the nasal passages (or mouth), pharynx and larynx. In this upper region, large airborne particles are filtered from the air and the air is warmed and partially humidified. Next the air passes through the trachea and bronchi. The bronchi bifurcate (split) into successively smaller bronchi all the way down to the terminal bronchioles. Each bifurcation results in a sharp change in direction and the larger paint particles are unable to negotiate the sharp turn and impact on the mucous layer. Rarely do particles greater than 6 μm succeed in traveling to the deeper respiratory zone (Fox, 1996:463).

Mucociliary Escalator Clearance

Two layers of fluid line the conducting zone of the respiratory system. The fluid at the base (nearest the lung tissue) is serous and has viscosity similar to water. The fluid on top is mucous and is more viscous than the lower layer. This thicker mucus captures many particles that impact this region (Bates, 1989:70). The mucociliary clearance mechanism occurs in the airways from the trachea down to the bronchioles and is well suited to trap and sweep away bacteria, inhaled particles and cellular debris (Bates, 1989:69). The paint particles trapped in the mucus are eventually removed from the body by expectoration or reintroduced into the gastrointestinal track of the body through ingestion.



The linear velocity of the mucous layer is influenced by ciliary beat frequency (Bates, 1989:4). Cilia move captured particles approximately 1.0 cm/min to the pharynx to be swallowed (Phalen, 1995:133-5).

Mucociliary escalation removes particles faster because the particle is transported by ciliary action to be swallowed or expectorated. If a paint particle containing Cr (VI) were to reach the respiratory level of the lung, the macrophages would eventually break down the components. Clearance of foreign particles in the lung can be accomplished by three major methods: mucociliary clearance, phagocytosis and coughing (Bouhuys, 1977:293). This thesis effort is focused on the clearance of paint particles by mucociliary escalation prior to reaching the alveoli.

The Respiratory Zone.

Beyond the conducting zone, the respiratory zone includes the respiratory bronchioles, alveolar ducts, alveolar sacs and alveoli. This is where gas exchange between air and blood occurs. The body's main clearance mechanism for foreign particles in the alveolar region is lung macrophages. *Lung macrophage* is a type of cell that brings a particle of foreign matter into the cell and breaks it down. However, compared to the mucociliary escalator in the conducting zone, lung macrophage activity is a slower mechanism for removal of foreign particles.

Particle Size Deposition in the Lung

Typical particle deposition in the lung of an adult male is shown in figure 2 (Health Effects Institute, 1998: 2). Different sections of the lung receive different particle distributions. Of the particles that enter the respiratory system, the respiratory zone receives 40% of particles between 0.01 and 0.1 ìm and 20% of the particles between 1 and 10 ìm. The conducting zone receives 60% of the total particles ranging in size from 0.001 to 0.1 ìm and 80% of the total particles ranging in size from 1 and 100 ìm.

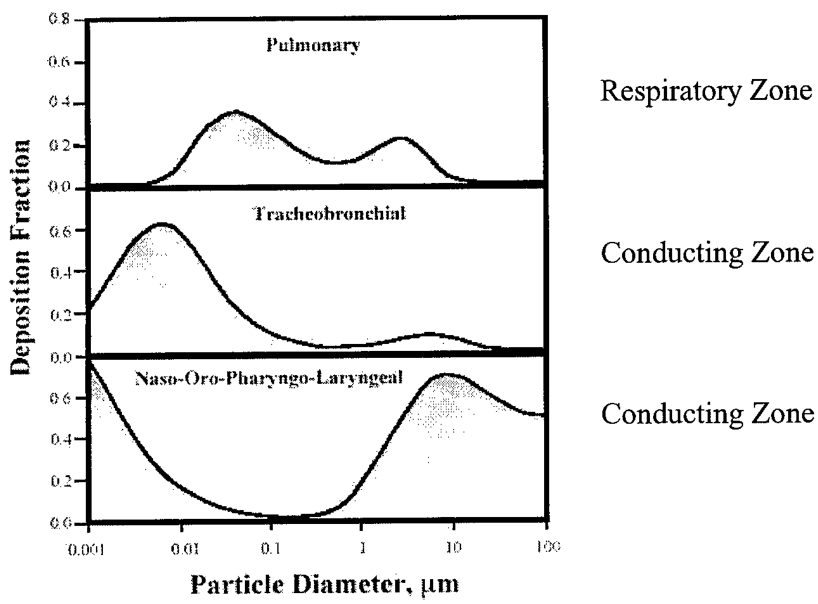


Figure 2. EPA Deposition of Particle Size (Health Effects Institute, 1998: 2).

III. Methodology

Overview

This chapter describes the equipment and methods used, followed by a discussion of the procedures developed to accomplish this research effort. The selections for residence times and sample digestion are discussed. The equipment used to discriminate particle size is described, as well as the peripheral collection equipment.

Experimental Design

The experiment is designed to collect primer paint particles into SLF and quantify the fraction of Cr (VI) that escapes the particle and dissolves into the surrounding SLF. The dissolution of Cr (VI) into the SLF assumes the paint particle was inhaled and is now imbedded in the serous layer of fluid in the lung. The turbulent method of collection exaggerates the efficiency of extraction *and* ignores the period of time required for deposited particles to penetrate the mucous layer into the serous layer, so the experimental design is very conservative.

Simulated Lung Fluid.

There are two types of SLF in the literature: simulated surfactant lung fluid (SSLF) and simulated interstitial lung fluid (SILF). The difference between SSLF and SILF is a surface-active component (dipalmitoyl lecithin: DPL) present in SSLF (Dennis, 1982:470). Biological fluids are difficult to recreate and lung fluid is no exception. Different variations of SLF were found in the literature but most can be traced to Gamble's 1952 formula. SLF has been used to test solubility of uranium compounds (Cooke, 1974: 69; Duport, 1991:121), titanium tritide particles (Cheng, 1997:633), dissolution of fibers (Christensen, 1992:83; Mattson, 1994:87; Mattson, 1994:857), and dissolution of yellowcake—U_3O_8, a product of uranium milling used for nuclear fuel enhancement (Dennis, 1982:469; Eidson, 1984:151). In addition to the standard salts, some formulas include preservatives to extend shelf life, or proteins to more closely mimic the natural lung fluid. Proteins may result in foaming of solution when the air is bubbled through, so SLF without proteins was selected. However, it is possible that proteins may play a role in effecting the breakdown of the paint matrix and, therefore, promoting release of Cr (VI).

An SLF formulation reported by Fisher and Briant (Fisher, 1994: 264) and shown in Table 1 was selected for this experiment. Moss (Moss, 1979: 447) reported a potential problem of precipitation of salts from SLF formulas due to high local concentrations when the salts are initially added to solution. Therefore, the Fisher SLF relied on a modified Gamble's solution, in which a 50% reduction in magnesium and calcium chloride salts eliminated the precipitation problem (Fisher, 1994:264).

The SLF was mixed in batches of 1 liter (L). SLF ingredients were added to 950mL of deionized (DI) water. Each ingredient was weighed using a Mettler scale to an accuracy of ± 0.1 mg. The ingredients were added sequentially in the order listed in Table 1. When the desired mass of each ingredient was attained, several drops of DI water were added to partially dissolve the ingredient. This enhanced the dissolution of each ingredient when added into the final volume and maximized ingredient transfer into the SLF mixture.

Table 1. Simulated Lung Fluid Ingredients

Description	Molecular Formula	Concentration in mg/L
Magnesium chloride	$MgCl_2 \cdot 6H_2O$	101
Sodium chloride	$NaCl$	6019
Potassium chloride	KCl	298
Sodium phosphate	$Na_2HPO_4 \cdot 7H_2O$	268
Sodium sulfate	Na_2SO_4	71
Calcium chloride	$CaCl_2 \cdot 2H_2O$	184
Sodium acetate	$NaH_3C_2O_2 \cdot 3H_2O$	952
Sodium bicarbonate	$NaHCO_3$	2604
Sodium citrate	$Na_3H_5C_6O_7 \cdot 2H_2O$	97

Midget Impinger.

Paint particles were collected by bubbling particle-laden air through the SLF using a midget impinger containing SLF. An impinger is a device that draws air through a conducting tube (#1 in Figure 3), releasing the air at the bottom of a narrow cylinder that contains a fluid (#2 in Figure 3). In these experiments, the air bubbles through the fluid and some paint particles become trapped in the fluid while the air continues to be drawn through a tube that leads to the air pump (#3 in Figure 3).

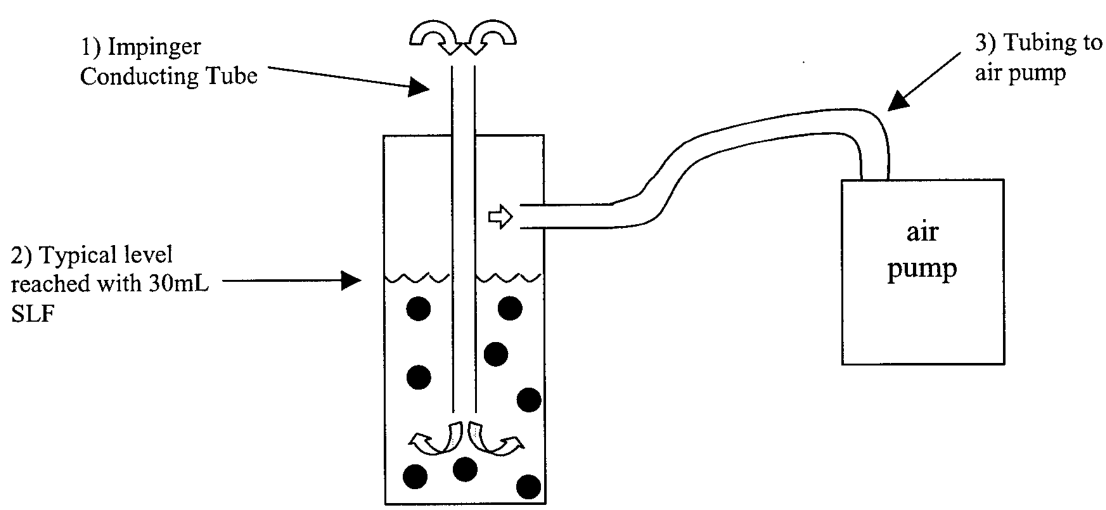


Figure 3. Midget Impinger

The impinger was connected to a Gilian® GilAir 5 air pump. Air is drawn through the pump at a specific rate. After preparing the impingers, the GilAir pumps were calibrated to 1.2 lpm using a Gilibrator Airflow Calibration System # 800286. An airflow rate of 1.2 lpm was selected to maximize particle capture between 1–20 μm.

Six impingers were used during spray painting for this thesis effort. An aliquot (50 mL) of SLF was added to each of three impingers and 50 mL of DI was added to each of the remaining three impingers. The three impingers containing SLF were placed side by side to simultaneously collect samples during spray painting operations. An additional impinger, containing DI was placed in the same area to determine particle size and particle number collected during overspray sampling. The remaining two impingers, containing DI, were used to determine background contribution of particles in the spray paint booth prior to sampling.

The air pumps for the four impingers (three SLF and one DI) were started less than a minute before spray painting began. The pumps were stopped less than a minute after painting operations had ended. Total sampling time was recorded. The conducting tubes of the impingers were replaced prior to each sampling period to be certain that residues in the tubes would not contaminate the next sample. After sample collection, the GilAir pumps were recalibrated to check flow rate. The recorded flow rate was the average of values measured during pre and post calibration.

Paint Booth.

The paint booth in which the samples were collected is located in a humidity- and temperature-controlled facility. The paint booth used for this sampling effort measures

81"x72"x60" and has an average air flow of 151 feet per minute. The temperature during sample collection was 22 ± 2 °C and the humidity during sample collection was 63 ± 3 % (99% confidence interval). Sampling location, flow rate, painting procedure, and climate were held constant to avoid variation from unwanted sources. The paint samples were collected in a paint booth utilizing the same application equipment and techniques used during typical spray painting operations. A DeVilbiss high-volume low-pressure (HVLP) paint spray gun, (product number JGHV-531), fitted with a 46MP air cap, was used to apply the paint.

Paint base and activator were mixed at a 3:1 ratio, per manufacturers' specifications, and allowed a 30-minute induction time before the paint was sprayed for sampling. For each sampling period 300 mL of the activator was mixed with 900 mL of the base component. Sample periods ranged from 10 to 92 minutes in duration.

A cardboard box was placed around the impingers (Figure 6) to slow the movement of spray paint particles, which provided an adequate number of paint particles for collection. The HVLP spray gun was positioned approximately 12 inches from the front of the box and sprayed parallel to the face of the box, approximately 8 inches from the target. The placement of the target and the HVLP paint gun were selected to avoid collection of large paint particles. Both flow rate and pressure knobs on the spray gun were set to achieve uniform and satisfactory atomization with a nozzle pressure of 1.5 psi. Paint was continuously applied to the test panel throughout the entire sampling period. A 24-by-18-inch test panel was installed adjacent to the opening of the box and set at an angle of approximately 30 degrees from normal to the flow of paint. Figure 4 illustrates the sample collection stand (#1), test panel (#2) and HVLP spray paint nozzle (#3), which are positioned for sampling.

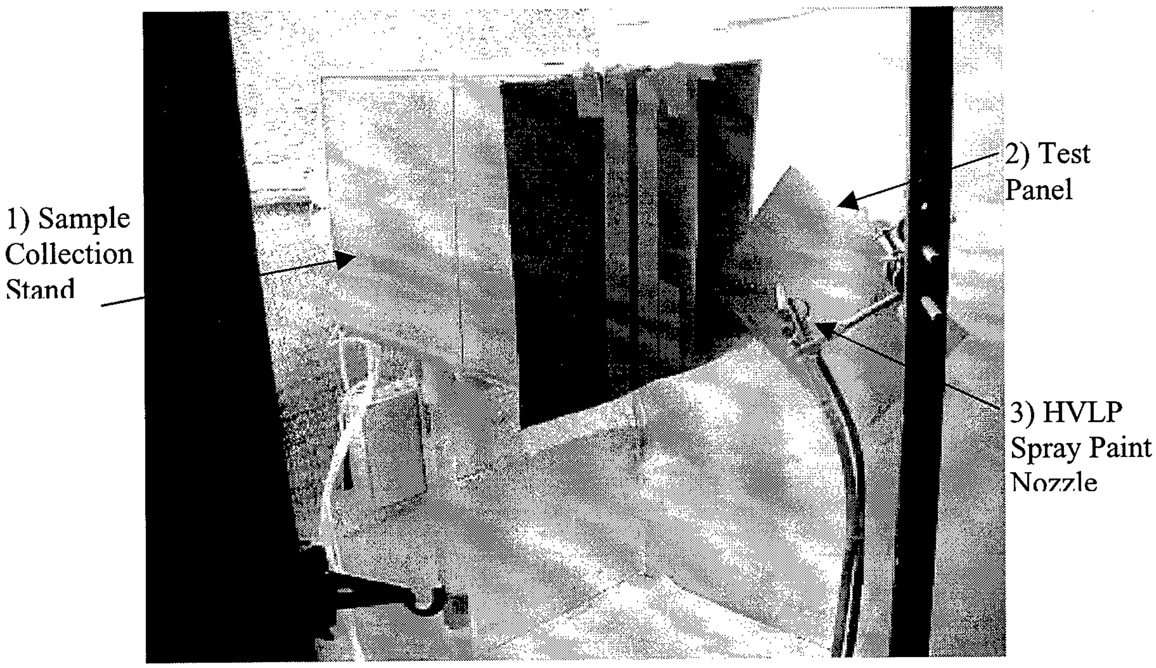


Figure 4. Sample Collection Stand & Paint Booth

Particle Counter.

A volumetric liquid particle counter (Liquilox S05), made by PMS Inc., uses a volumetric particle LiQuilaz® sensor that counts and measures particles suspended in liquids. The particle counter is capable of detecting particle counts within 15 distinct particle size ranges—from a minimum particle size of 0.5 μm through a maximum particle size of 20 μm. The range limits can be adjusted throughout the 0.5 – 20.0-μm particle size range with the manufacturer's software.

Because the salts in the SLF interfered with particle counting, a separate impinger filled with DI water was used for the purposes of establishing the size and quantity distribution during particle collection. Contribution of particles from spray painting was determined through the particle count measurements performed on the impingers containing DI water. To determine the net particle count from painting, the particle counter drew an aliquot directly from the center of the sample volume for analysis. The particles collected in the impinger without painting (background) was subtracted from the particles collected during spray painting to yield the total particle contribution from spray painting. The particles counted in the DI water from each sample run were assumed to be representative of the sampling run. The particles counted were applied to all three SLF samples collected during the sample run.

Residence Time.

Residence time of the paint particles in the SLF should mimic the residence time of foreign particles in the human lung. Mucociliary transport has been estimated from whole-lung clearance curves. The particle size range that is of most interest is 1 – 20 μm because this size range is most likely to be inhaled and deposit in the tracheobronchial tree. A particle that impacts on the tracheobronchial tree, is usually cleared via mucociliary mechanisms within 24–48 hours (Brain, 1994:120). The potential contact time of a particle in the conducting zone of the lung is the area of interest, so 24- and 48-hour residence times were selected. To determine whether residence time affected the dissociation of $SrCrO_4$ from the sample, two groups of collected samples were incubated at body temperature (37°C) for 24 and 48 hours, respectively.

Centrifuge.

The Eppendorf model 5810R centrifuge was used to separate the paint particles from the SLF (Figure 5). The Cr (VI) concentration of the initial sample, which contains paint particles, provided the total Cr (VI) concentration of the SLF sample. After the selected 24-hour or 48-hour residence time, the SLF samples were placed in the centrifuge to eliminate the paint particles and leave only the Cr (VI) dissolved in the SLF. The concentration of dissolved Cr (VI) remaining in the SLF (without particles) represents the dissolution of Cr (VI) from paint particles in SLF at the residence times of 24 and 48 hours.

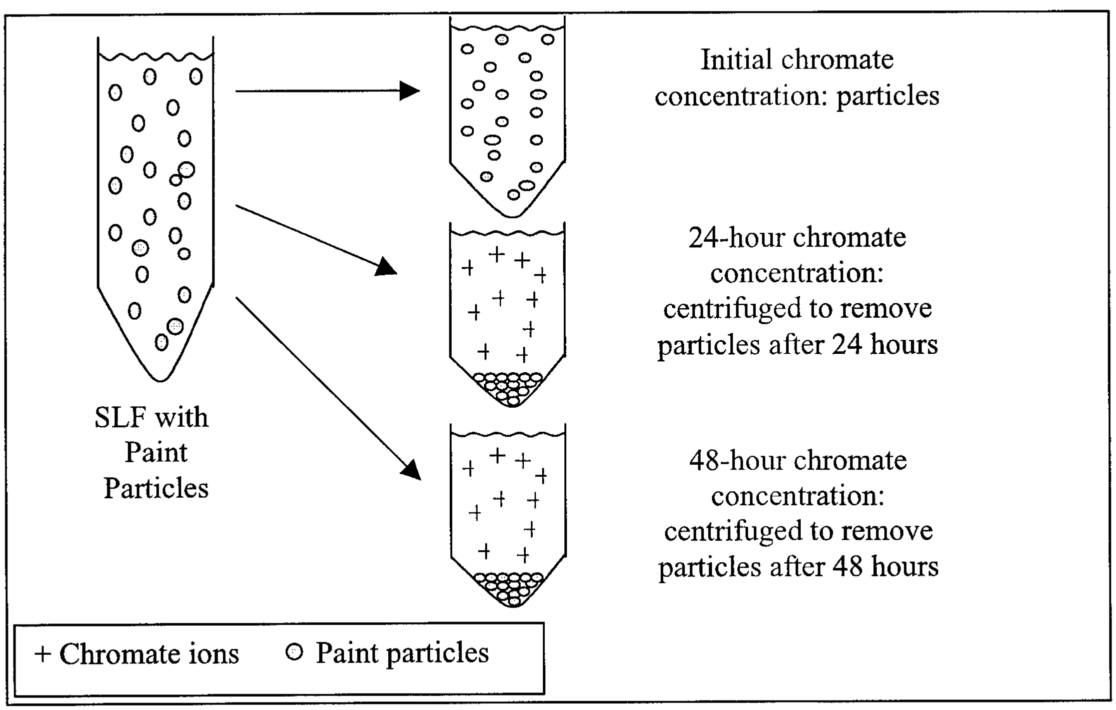


Figure 5. SLF Sample

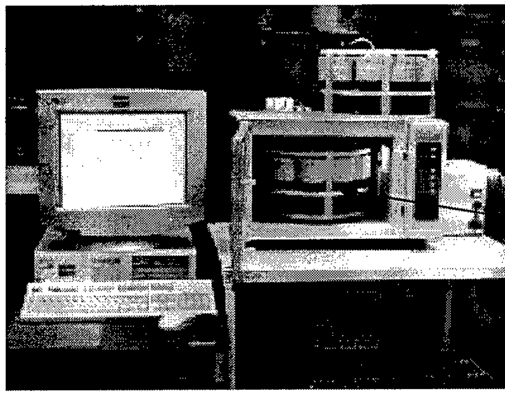
Sample Preparation and Analysis.

In preparation for quantifying Cr (VI) concentration, the 30mL of SLF available for analysis was transferred into the respective sample analysis containers. To determine the total chromium in the initial sample, an aliquot was pipetted from the center of the sample volume and transferred directly into a microwave digestion vessel. For 24- and 48-hour incubations, an aliquot was pipetted from the center of the sample volume and transferred into polypropylene centrifuge tubes. After storage for 24 or 48 hours at 37 °C, the samples were centrifuged for 20 minutes at 4000 rpm. The supernatant liquid was extracted, digested, and analyzed for Cr (VI) concentration.

Sample Digestion.

To prepare all samples for AAS analysis, particles in samples must be completely decomposed so that the AAS can measure the entire amount of chromium present in each sample. By design (and supporting the premise of this research project), primer paints polymerize rapidly to form a robust, cross linked lattice structure. To liberate chromium for analysis, complete digestion with nitric acid is required to thoroughly decompose the paint. Concurrent application of microwave energy shortens the digestion time and ensures complete destruction of the paint particles.

The OI Analytical Microwave Digestion System (Figure 6) was used to decompose the paint samples. No procedure is reported for decomposing the paint samples collected for this thesis effort. However, microwave digestion methods for paint chips exist in EPA method 3050A and NIOSH Method 7300. The procedures for these methods were combined and modified for this thesis sample digestion. Preparation comprised diluting the sample with an equal volume of 70% nitric acid and digestion at 50 psig for 5 minutes and 70 psig for 25 minutes.



Microwave carousel filled with digestion vessels

Figure 6. Microwave Digestion System

Atomic Absorption Spectrometry.

Atomic Absorption Spectroscopy (AAS) measures the interaction of light with atoms. AAS uses either a flame or a graphite furnace to create a plasma from a liquid sample containing an analyte. Because samples were expected (or could be diluted as necessary) to contain less than 1 ppm chromium, a GBC Avanta AAS, fitted with an optional autosampler and configured for the more-sensitive graphite furnace procedure, was used to quantify chromium concentration in all samples.

The GBC AAS autosampler option was utilized to introduce a volume of 10 microliters (ì l) of sample automatically into the graphite furnace tube. The AAS method is presented in Table 2. First, the tube is heated by passing current through the tube. In the drying step (Step 1), the sample is heated to remove all water. The drying step must be done slowly to avoid splattering and possible loss of sample. Argon gas flows to remove evaporated vapors. The charring and pyrolysis steps are Steps 2 and 3. These steps destroy the organic matrix components leaving the analyte in a less complex matrix. Steps 2 and 3 further remove undesired components of the sample but are completed at a temperature low enough to avoid volatizing the analyte of interest. Step 4 is atomization where the chromium ions are excited. The argon flow is stopped and the instruments absorbance measurements are recorded. The last Step (5) is the cleaning step. This step raises the temperature again and forces gas through the tube to clean any residual substance left in the tube, preparing it for the next sample.

Table 2. Atomic Absorption Method Parameters

Steps	Parameters				
	Final Temp (°C)	Ramp Time (s)	Hold Time (s)	Gas	Read Signal
1: Drying	80	5.0	10.0	Argon	Off
2: Charing	130	30.0	10.0	Argon	Off
3: Pyrolysis	1400	15.0	15.0	Argon	Off
4: Atomization	2500	1.4	1.6	None	On
5: Clean	2700	0.5	1.5	Argon	Off

Chromium has several absorption wavelengths. The wavelength selected was 357.9 nm with a 0.2 mm slit width. The hollow cathode lamp current was 6.0 mA.

GBC Avanta Atomic Absorption Spectrometer with auto sampler was used to quantify chromium concentration in each sample. The auto mix function was used to create dilutions from a stock concentration for calibration standards. A five-point calibration curve method was used.

A High Purity Standards 75 ppb Cr (VI) certified standard was used in the GBC AAS to auto-mix 7.5, 20, 40, 60, and 75 ppb chromium concentrations. A linear least squares regression analysis was used to create the calibration curve. A regression factor (R^2) of 0.980 or higher was required for acceptance.

IV. Results

Manufacturer-Specific Paint Sample Results

Data Measured for the Deft primer are presented in Figure 7 and data for the DeSoto primer are presented in Figure 8. The initial, 24-hour, and 48-hour chromium concentrations for the Deft and DeSoto paints are grouped on the graphs. The values on the graph above the "Initial [Cr] w/ particle" label (for samples that included both the solution and the paint particles) was determined to establish the total concentration of Cr (VI) contributed by spray painting. Because these samples were centrifuged to eliminate particles immediately before analysis, the values on the graph above the "24-hour [Cr] no particles" label indicate the fraction of Cr (VI) that dissolved out of the particles during 24 hours of incubation at 37 C. Likewise, the values on the graph above the "48-hour [Cr] no particles" label indicate the fraction of Cr (VI) that dissolved from the particles during 48 hours of incubation at 37 C prior to centrifugation and analysis. The original analytical results of the Cr (VI) analyses for Deft and DeSoto are presented in Appendix B-1 and B-2, respectively.

The [Cr] concentration results for both Deft and DeSoto paint follow a similar trend. When the initial [Cr] concentration is high, the 24-hour and 48-hour samples appear to have a significant reduction in [Cr]. This would indicate that a large fraction of [Cr] remains trapped in the paint particles. However, when the initial [Cr] are low (<200 ppb), there does not appear to be a reduction in [Cr] at 24-hours and 48-hours. This would imply that most of the Cr (VI) at low initial [Cr] escapes the particles and is dissolved into the surrounding SLF. This trend appears to be the same for both manufacturers.

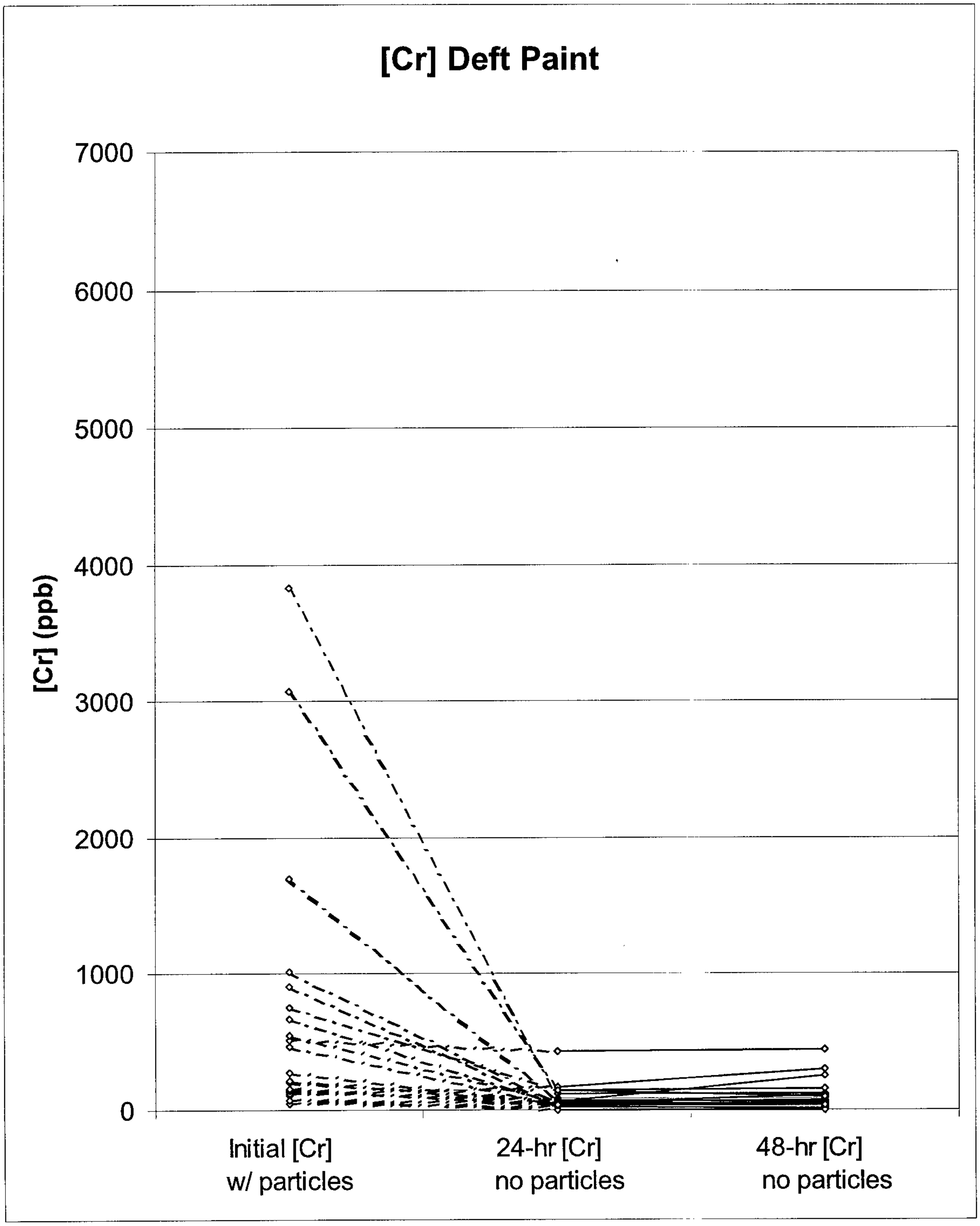


Figure 7. Chromium Concentration of Deft Samples

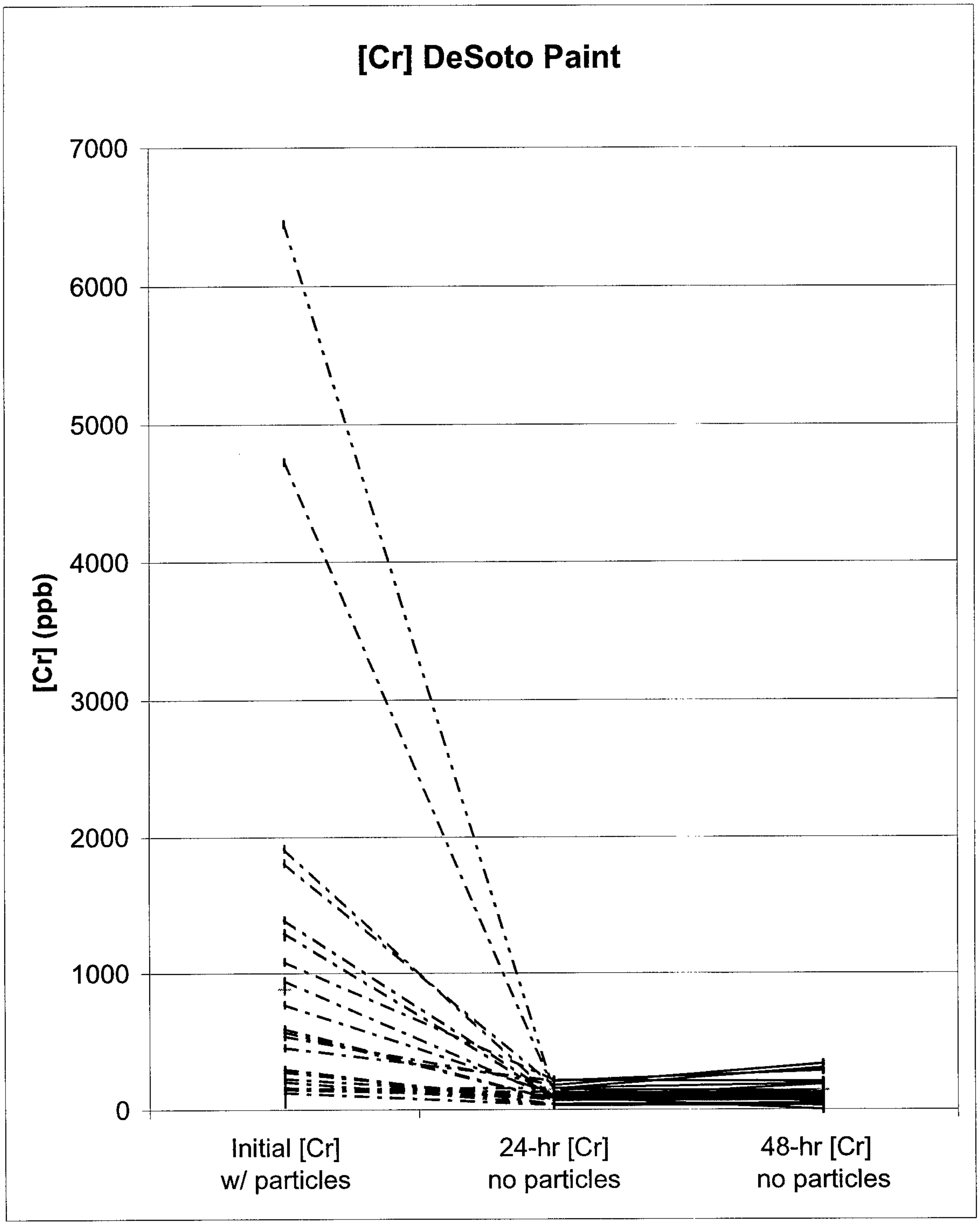


Figure 8. Chromium Concentration of DeSoto Samples

Difference Between Residence Times.

One research goal was to determine if residence time influences the dissociation of Cr (VI) in SLF. If residence time influences the dissociation of Cr (VI) in SLF, a difference should exist between the Cr (VI) concentrations in the 24 and 48-hour sample results. A paired t-test is performed between the 24-hour and 48-hour residence time concentrations to determine if there is a significant difference between the two residence times. The results of the analysis of the t-test comparison of means (Appendix C) indicate that there is not a significant difference in mean Cr (VI) concentrations of the two residence times between the two manufacturers.

The results of analysis for each of the initial, 24-hour, and 48-hour sampling period samples, for both manufacturers, are averaged and presented in Figure 9. The 95% confidence interval is displayed on the graph. The 95% confidence interval for the initial concentration is 822 $\pm$ 231 ppb. The 95% confidence interval for the 24-hour residence time concentration is 95 $\pm$ 15 ppb. The 95% confidence interval for the 48-hour residence time concentration is 112 $\pm$ 25 ppb. The data seems to reflect that the average initial results of sampling were much higher than the corresponding 24-hour and 48-hour sample results. Additionally, the initial results have a significantly larger confidence interval than the corresponding 24-hour and 48-hour sample results. The results of sampling from both manufacturers seem to follow a similar trend—regardless of the initial concentration; the 24-hour and 48-hour residence time concentration appears to achieve a consistent concentration from approximately 50-100 ppb.

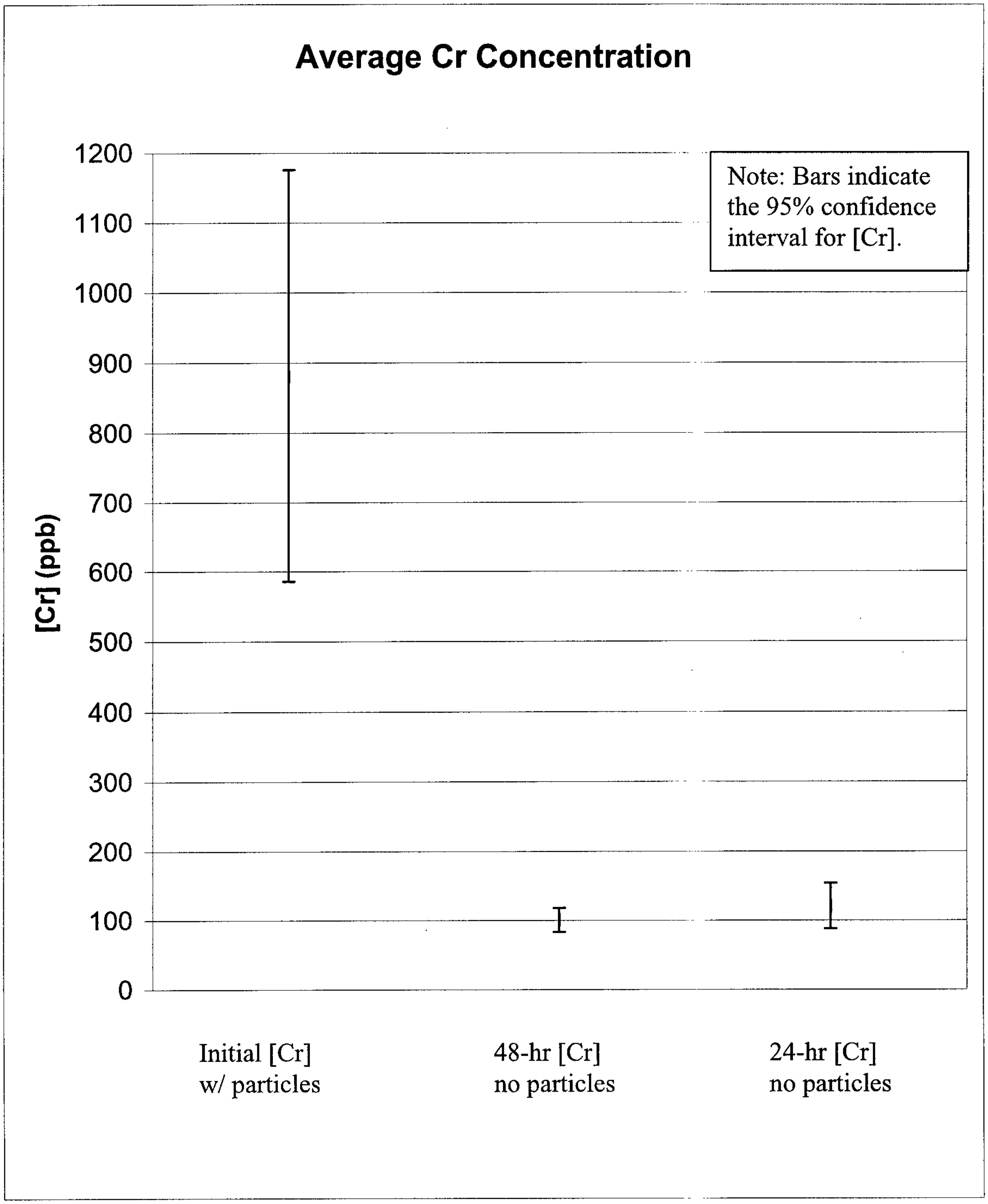


Figure 9. Average Chromium Concentration

Particle Size Distribution Collected.

A particle counter was used to determine the number and size of paint particles collected during sampling (Appendix B). The size distribution of paint particles for each sample is plotted in Figure 10. The paint particles per milliliter are quantified by bin size. Figure 10 indicates that the majority of particles collected were between 1-3.5 μm in diameter. The two samples, highlighted in Figure 10 with thicker lines, have a higher number of paint particles in the larger bin sizes compared to most other samples. The initial three Cr (VI) concentration associated with these two samples are also identified. The higher fraction of larger-sized particles seems to have a direct impact on the high initial Cr (VI) concentration results.

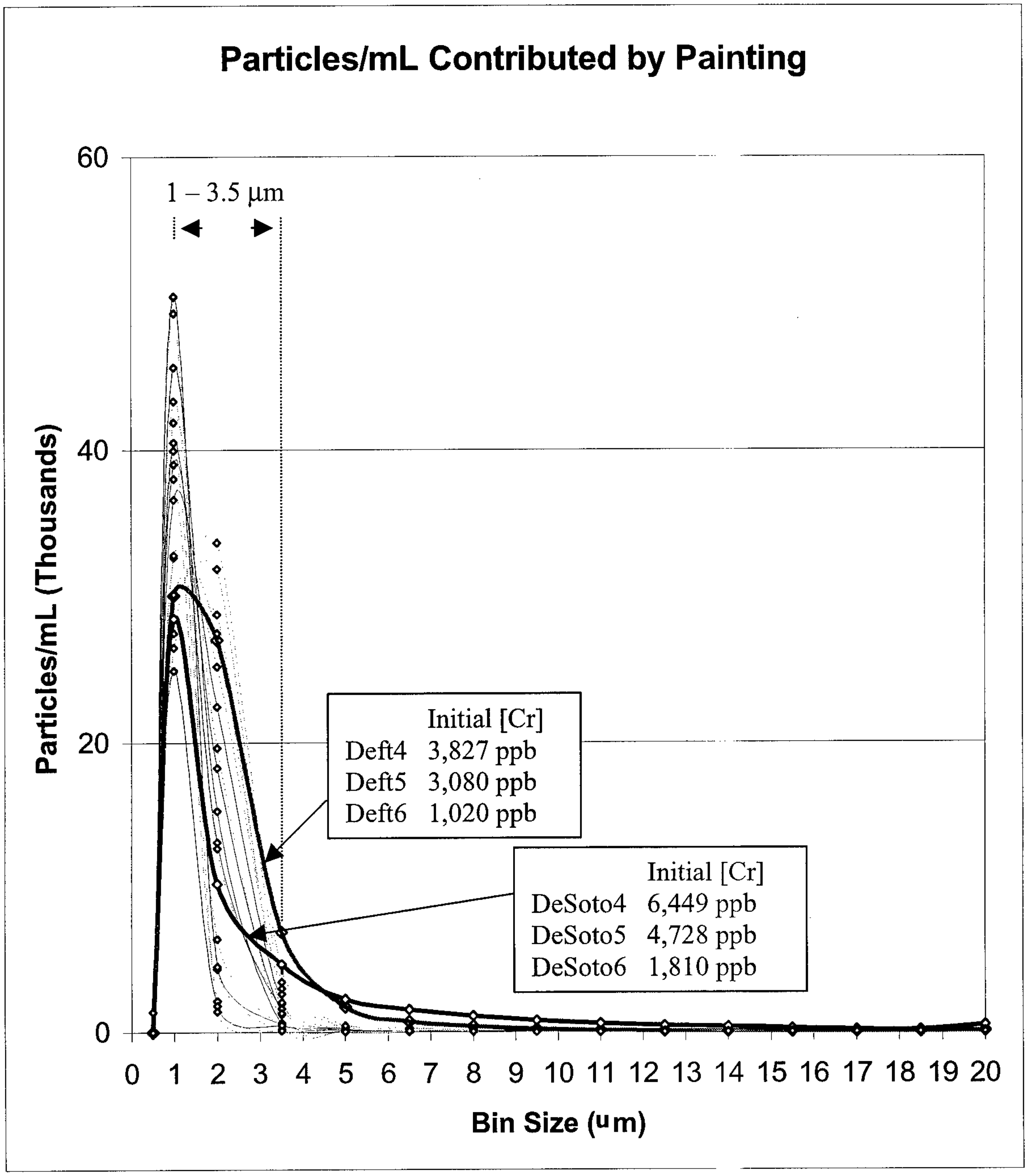


Figure 10. Paint Particles Contributed

Particle Surface Area Comparison.

To determine the contribution of Cr (VI) from the larger-sized particles, the total particle surface area was determined. The analysis of particle surface area provides a clearer insight on the influence of particle size with concentration.

The total surface area per milliliter of the paint particles was determined by calculating the surface area of the particles within each bin. The surface area of each particle is 4ðr^2, where r is the average diameter for each bin. The number of particles collected during sampling was multiplied by the average surface area for the bin to result in the total surface area within each bin. The seemingly larger surface area in the 20μm bin may be much less noticed with higher instrument resolution.

Figure 11 shows that most of the paint particles are distributed between 1 – 3.5 μm, with virtually no contribution from larger paint particle sizes. However, the two thicker lines shown not only have a large contribution from larger particles but these samples also had very high initial concentrations relative to the other samples analyzed. The particle distribution with the thicker lines also had much less in [Cr] at 24 and 48-hours, which means that very little Cr (VI) dissociates from the particles. These results seem to suggest that larger particles lock in more chromium than the smaller (1 – 3.5 μm) particles. The smaller particles may allow most of the Cr (VI) to dissociate which would explain the relatively small difference between the initial and the 24 and 48-hour concentrations when only smaller particles were collected. In other words, when only the smaller particles are involved, a large fraction of Cr (VI) would dissolve into the SLF. When smaller and larger particles were collected, about the same amount of Cr (VI) would dissolve into the SLF as the samples where only small particles were collected.

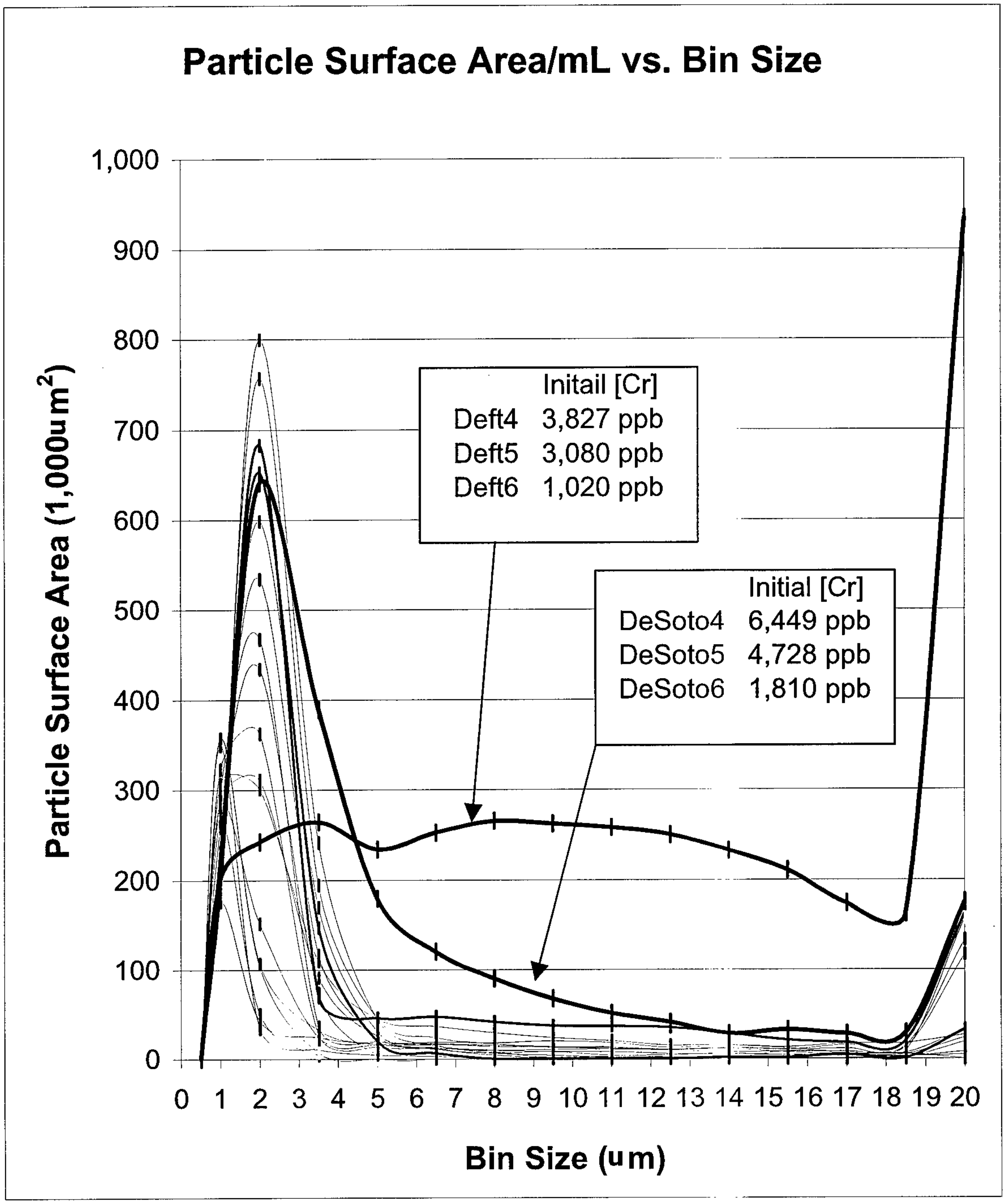


Figure 11. Average Bin Particle Surface Area

$SrCrO_4$ Saturation Limit in SLF.

The solubility of $SrCrO_4$ in SLF was compared to the solubility of $SrCrO_4$ in water. This provided insight into the saturation point for $SrCrO_4$ in SLF. It was important to know the saturation limit of $SrCrO_4$ in the SLF. Over- saturating the SLF could affect the chromium dissolution from the initial to the 24-hour and 48-hour sample residence times. The solubility of $SrCrO_4$ in water is 1,200 ppm at 15 °C (Weast, 1985: B-147). The solubility of $SrCrO_4$ (as chromium) in SLF at 37 °C was determined to be 240 ppm (Morgan, 2000:39). The chromium concentration of the samples may have been biased if the chromium concentration approached the saturation limit of $SrCrO_4$ (as chromium) in SLF. The chromium concentration of the samples (highest [Cr] = 6449 ppb) is far below the saturation limit (240,000 ppb) so chromium concentrations were not affected by being close to the saturation limit.

Quality Testing Results.

Chromium was analyzed in blanks and in sample containers to test for chromium additions from unknown sources. Blanks were prepared using only SLF and processed identically to all other samples and then analyzed. The concentration of the chromium in the straight SLF samples was below the AAS method detection limit (0.02 ppb). The lack of detectable chromium in the SLF implies all chromium concentrations from collected samples originate from spray painting operations.

V. Discussion

Conclusions

This research study focused on three primary research goals. The first goal was to develop a method for measuring the amount of metal dissociation from a particle in SLF. The particle counter verified that paint particles could be trapped into an SLF. In order to measure the dissolution of chromium from paint particles into SLF, there had to be paint particles in the SLF for the dissolution to occur. The particle counter provided a means of verification for the quantity and size of paint particles contributing their chromium to the SLF.

A second goal was to determine whether the residence time of paint particles in SLF significantly affected the amount of Cr (VI) dissolving into the SLF. To determine whether time had an influence on dissolution, paint particles in the samples were allowed to soak in the SLF for 24 and 48-hours. The fraction of Cr (VI) dissolved into the SLF at the 24 and 48-hour residence times were compared and the difference was *not significantly different*, so the dissolution process is not time-dependent at the 24- and 48-hour time range.

The final objective of this thesis was to evaluate the fraction of total Cr (VI) that dissociates from the collected primer paint particles into the SLF. The data strongly suggest that *dissociation is significantly suppressed.* However, a size-dependent relationship with chromate dissociation exists that is beyond the scope of this research.

Follow-on Research

Several aspects to further research would be the efficiency of particle collection. One could follow standard guidelines to properly characterize the particle size collected in the equipment set-up. Analysis of the particle size would greatly enhance understanding.

The airflow from the pumps should be regulated with a manifold system and flow meter. Regulating the airflow to all impingers will enhance the opportunity to target particle size and quantity of particles collected through adjustment of the airflow. The bubble size generated in the SLF can also be adjusted through controlling the airflow. Upon visual inspection of the bubbles generated during sampling, the size of the bubbles generated were many orders of magnitude larger than the particles being collected. Large bubbles of air will result in lower overall surface area for contact of paint particles with the SLF. This may bias the particle size distributions collected. Particle surface area for this thesis effort was skewed toward the smaller sized particles, increasing the number of particles collected may result in a more equal representation of all particle sizes. Establishing controls for particle size will lead future research to which parameters are most important in dissociation of chromium in paint particles to body fluids.

Water-based, polysulfide, and polyurethane paints, authorized by the military and federal specifications, should be studied to determine if a similar relationship between particle size and dissociation exists.

Availability of Cr (VI) to the industrial worker is of great concern. Greater depth of follow-on research will be key to determining the human hazards associated with chromium in paint overspray.

Interest in chromium compounds stem from the fact that workers have an increase risk of lung cancer due to the handling, processing, and application of chromate-containing compounds. The data collected for this thesis effort suggest that the Cr (VI) escaping paint particles into SLF is hindered. The hindrance of Cr (VI) escaping the paint particles into SLF was not apparent in the studies OSHA evaluated, where the Cr (VI) was in an acid-mist or dust form with no paint matrix to hinder the dissociation of Cr (VI) into body fluids.

Appendix A-1: Deft MSDS

Page: 1 MATERIAL SAFETY DATA SHEET Printed : 02/08/01

For Coatings, Resins and Related Materials

Revised : 11/30/99

SECTION I - PRODUCT IDENTIFICATION

Manufacturer: DEFT, INC. (CAGE CODE 33461)
17451 VON KARMAN AVENUE

IRVINE CA
92614

Information Phone: (949) 474-0400
Emergency Phone: (800) 424-9300
CHEMTREC Phone: 800-424-9300

Product Class: TYPE I, CLASS C
Trade Name : MIL-PRF-23377G (MIL-P-23377G)
Product Code : 02Y040
C.A.S. Number: NONE

Hazard Ratings: none -> extreme 0 ---> 4
Health - 4
Fire - 3
Reactivity - 1

SECTION II - HAZARDOUS INGREDIENTS

Ingredients	CAS #	Weight %	ACGIH TLV	ACGIH STEL	OSHA PEL	OSHA STEL	VP mm HG
BENZENE, 1-CHLORO-4 TRIFLUOROMETHYL	98-56-6	< 5.	N.E.	N.E.	N.E.	N.E.	5.3 @ 68F
BENZENE, 1-CHLORO-2 TRIFLUOROMETHYL	88-16-4	< 0.1	N.E.	N.E.	N.E.	N.E.	5.3 @ 68F
n-BUTYL ACETATE	123-86-4	< 5.	150 ppm	200 ppm	150 ppm	200 ppm	13 @ 68F
METHYL n-PROPYL KETONE	107-87-9	25.	200 ppm	250 ppm	200 ppm	250 ppm	27.8 @ 68F
STRONTIUM CHROMATE	7789-06-2	25.			1 ppm	N.E.	
		The ACGIH TWA for Strontium Chromate (CAS 7789-06-2) as Cr is 0.0005 mg/m3.					
C9&10 AROMATIC HYDROCARBON	64742-95-6	< 5.	N.E.	N.E.	N.E.	N.E.	3 @ 68F
		Manufacturer recommends a PEL of 100 ppm.					
N-METHYLPYRROLIDONE	872-50-4	< 1.	N.E.	N.E.	N.E.	N.E.	.5 @ 77F
		N METHYLPYRROLIDONE, CAS # 872-50-4, ESTIMATED TLV TWA 100 PPM. (PER GAF CORPORATION)					

THE ABOVE LISTED PRODUCTS ARE ON THE TSCA INVENTORY LIST.
ALSO ANY UNLISTED INGREDIENTS.

N.E. = Not Established

SECTION III - PHYSICAL DATA

Boiling Range: 213 - 396 Deg. F
Evap. Rate: 1.65 x n-Butyl Acetate
Volatiles vol % 44 % Wgt% 27.6

Vapor Density: Heavier than Air.
Liquid Density: Heavier than Water.
Wgt per gallon: 11.23 Pounds.
Spec. Gravity: 1.34914

Appearance: YELLOW LIQUID WITH SOLVENT ODOR
V.O.C.: 361 G/L
SOLUBILITY IN WATER: Insoluble PH: Not applicable
AUTOIGNITION TEMPERATURE: No information found
DECOMPOSITION TEMPERATURE: No information found
CORROSION RATE: No information found
VISCOSITY: Thin liquid to heavy viscous material

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

Flammability Class: IB Flash Point: 46 F TCC LEL: 0.90% UEL: 10.50%

EXTINGUISHING MEDIA:
FOAM, ALCOHOL FOAM, CO2, DRY CHEMICAL, WATER FOG**

SPECIAL FIREFIGHTING PROCEDURES:
Full fire fighting equipment with self-contained breathing apparatus and full protective clothing should be worn by fire fighters. Water may be used to cool closed containers to prevent pressure build-up, auto ignition or explosion.

UNUSUAL FIRE & EXPLOSION HAZARDS:
Keep containers tightly closed. Isolate from heat, sparks, electrical equipment and open flame. Closed containers may explode when exposed to extreme heat. Application to hot surfaces requires special precautions. During emergency conditions overexposure to decomposition products may cause a health hazard. Symptoms may not be immediately apparent.

SECTION V - HEALTH HAZARD DATA

PERMISSIBLE EXPOSURE LEVEL:
SEE SECTION II, HAZARDOUS INGREDIENTS.

EFFECTS OF OVEREXPOSURE:
INHALATION: Irritation of the respiratory tract & acute nervous system depression characterized by the following progressive steps: headache, dizziness, staggering gait, confusion, unconsciousness or coma.
SKIN AND EYE CONTACT: SKIN: Contact with the skin can cause irritation. Symptoms may be swelling, redness, and rash.
EYES: Liquid, aerosols, or vapors are irritating and may cause tearing, redness, and swelling accompanied by a stinging sensation.
SKIN ABSORPTION: Prolonged or repeated contact can cause moderate irritation, drying, and defatting of the skin which can cause the skin to crack.
INGESTION: Acute: Can result in irritation and possible

Page: 1 MATERIAL SAFETY DATA SHEET Printed : 02/28/01
For Coatings, Resins and Related Materials
Revised : 11/30/99

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	The ACGIH TWA for Strontium Chromate (CAS 7789-06-2) as Cr is 0.0005 mg/m3.						
18610 AROMATIC HYDROCARBON	64742-95-6	< 5.	N.E.	N.E.	N.E.	N.E.	3 @ 68F
	Manufacturer recommends a PEL of 100 ppm.						
N-METHYLPYRROLIDONE	872-50-4	< 1.	N.E.	N.E.	N.E.	N.E.	.5 @ 77F
	N-METHYLPYRROLIDONE, CAS # 872-50-4, ESTIMATED TLV TWA 100 PPM. (PER GAF CORPORATION)						

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V.O.C.: 361 G/L
SOLUBILITY IN WATER: Insoluble PH: Not applicable
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CORROSION RATE: No information found
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EXTINGUISHING MEDIA:
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UNUSUAL FIRE & EXPLOSION HAZARDS:
Keep containers tightly closed. Isolate from heat, sparks, electrical equipment and open flame. Closed containers may explode when exposed to extreme heat. Application to hot surfaces requires special precautions. During emergency conditions overexposure to decomposition products may cause a health hazard. Symptoms may not be immediately apparent.

SECTION V - HEALTH HAZARD DATA

PERMISSIBLE EXPOSURE LEVEL:
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INHALATION: Irritation of the respiratory tract & acute nervous system depression characterized by the following progressive steps: headache, dizziness, staggering gait, confusion, unconsciousness or coma.
SKIN AND EYE CONTACT: SKIN: Contact with the skin can cause irritation. Symptoms may be swelling, redness, and rash.
EYES: Liquid, aerosols, or vapors are irritating and may cause tearing, redness, and swelling accompanied by a stinging sensation.
SKIN ABSORPTION: Prolonged or repeated contact can cause moderate irritation, drying, and defatting of the skin which can cause the skin to crack.
INGESTION: Acute: Can result in irritation and possible

corrosive action in the mouth, stomach tissue and digestive tract. Vomiting may cause aspiration of the solvent, resultin in chemical pneumonitis.

HEALTH HAZARDS (ACUTE AND CHRONIC)

ACUTE: Vapors are irritating to eyes, nose, and throat. Inhalation may cause headaches, difficult breathing and loss consciousness

CHRONIC: Prolonged contact will cause drying and cracking of skin, due to defatting action. Skin sensitization, asthma or other allergic responses may develop. Repeated and prolonged exposure may cause delayed effects involving the blood, gastr intestinal, nervous and reproductive systems.

PRIMARY ROUTE(S) OF ENTRY:

TOPICAL (SKIN CONTACT): Yes

INGESTION (GASTRO-INTESTINAL): No

INHALATION (LUNGS): Yes

CARCINOGENICITY:

NTP?: YES, IARC MONOGRAPHS?: YES, OSHA REGULATED?: YES

MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE:

Asthma and any other respiratory disorders. Skin allergies, eczema, and dermititis.

-FIRST AID:

INHALATION: Move to an area free from risk of further exposure Restore breathing. Asthmatic type symptoms may develop and ma be immediate or delayed by several hours. Obtain medical attention.

SKIN: Remove contaminated clothing. Wash affected areas thoroughly with soap and water. Wash contaminated clothing thoroughly before reuse.

EYES: Flush with clean lukewarm water (low pressure) for at least 15 minutes, occasionally lifting eyelids. Obtain medical attention.

INGESTION: Do not induce vomiting. Do not give anything to an unconscious person. Obtain medical attention.

SECTION VI - REACTIVITY DATA

STABLITY: [ ] Unstable [x] Stable

HAZARDOUS POLYMERIZATION: [ ] May occur [x] Will not occur

-INCOMPATIBILITY

STRONG OXIDIZING AGENTS AND STRONG LEWIS OR MINERAL ACIDS.

-CONDITIONS TO AVOID:

HIGH TEMPERATURES, SPARKS, OR OPEN FLAMES. AVOID UNCONTROLLED REACTIONS WITH AMINES.

-HAZARDOUS DECOMPOSITION PRODUCTS:

BY HIGH HEAT/TEMPERATURE: Carbon monoxide, carbon dioxide, and oxides of nitrogen. Aldehydes and acids may be formed dur combustion. Chromium oxides when burned.

SECTION VII - SPILL OR LEAK PROCEDURES

-STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

Evacuate all non-essential personnel. Remove all sources of ignition (flame, spark sources, hot surfaces). Ventilate area Contain and remove with inert absorbent and non-sparking tools

-WASTE DISPOSAL METHOD:

Waste must be disposed of in accordance with federal, state, a local environmental control regulations. Empty containers must be handled with care, due to product residue and flammable va DO NOT incinerate closed containers.

ALSO SEE SECTION IV, V, VI, FOR OTHER PRECAUTIONS.

EPA HAZARDOUS WASTE NUMBER/CODE: D001, D007, F003, F005

HAZARDOUS WASTE CHARACTERISTICS:

IGNITABILITY: YES

CORROSIVITY: NO

REACTIVITY: YES

SECTION VIII - SPECIAL PROTECTION INFORMATION:

-RESPIRATORY PROTECTION:

A respirator that is recommended or approved for use in an organic vapor environment (air purifying or fresh air supplied is necessary. Observe OSHA regulations for respirator use. Ventilation should be provided to keep exposure levels below t OSHA permissible limits.

-VENTILATION:

Exhaust ventilation sufficient to keep the airborne concentrations of solvent vapors or mists below their respective TLV's must be utilized. Remove all ignition sources (heat, sparks flame, and hot surfaces).

-PROTECTIVE GLOVES:

Protective gloves are recommended (cotton, neoprene, rubber, polyethylene) to prevent skin contact.

-EYE PROTECTION:

The use of safety eyewear is recommended, including splash guards or side shields, chemical goggles or face shields.

-OTHER PROTECTIVE EQUIPMENT:

The use of long sleeve and long leg clothing is recommended. Remove and wash contaminated clothing before reuse.

SECTION IX - SPECIAL PRECAUTIONS

(continued on next page)

SECTION IX - SPECIAL PRECAUTIONS (cont.)

OTHER PROTECTIVE EQUIPMENT:

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING:
Store in buildings designed to comply with OSHA 1910.106 Avoid storing near high temperatures, fire, open flames, and spark sources. Store in tightly closed containers. Store in well ventilated areas.

OTHER PRECAUTIONS:
Keep containers tight and upright to prevent leakage. Prevent prolonged breathing of vapors or spray mists. Prolonged over-exposure may cause an allergic reaction. Aviod contact with skin and eyes. Do not take internally. Do not handle until the manufacturers safety precautions have been read and understood. Wash hands before eating, smoking, or using washroom. Smoke in smoking areas ONLY.

*** TRANSPORTATION INFORMATION ***

APPLICABLE REGULATIONS: 49 CFR (YES); IMCO (NO); IATA (NO)
MILITARY AIR (AFR 71-4) (NO)
PROPER SHIPPING NAME: Paint
REPORTABLE QUANTITY: Not applicable
HAZARD CLASS: Flammable liquid 3
THIS MATERIAL WHEN PACKAGED IN CONTAINERS OF 1 LITER OR LESS QUALIFIES AS PAINT IN LIMITED QUANTITY OF CLASS 3.
REQUIRED LABELS: Flammable liquid
U.S. POSTAL REGULATIONS: Not allowed to send via US POSTAL SERVICE.

*** DISCLAIMER ***

Information contained herein is furnished without warranty of any kind. Employers should use this information only as a supplement to other information gathered by them and must make independent determination of suitability and completeness of information from all sources to assure proper use of the materials and for the safety and health of their employees.

ACTUAL VOC DETERMINED PER EPA REFERENCE METHOD 24.

SECTION X - REGULATORY INFORMATION

-SARA 313:

This product contains the following toxic chemicals subject tc reporting requirements of section 313 of the Emergency Plannir and Community Right To Know Act of 1986 and of 40 CFR 372:

CAS#	Chemical Name	Percent by Weight
7789-06-2	STRONTIUM CHROMATE	22.54

This product contains chromium (hexavalent compound), 26% by weight.

-PROP 65-CARCINOGENIC

WARNING: This product contains a chemical known to the state of California to cause cancer.

CAS#	Chemical Name
7789-06-2	STRONTIUM CHROMATE

This product contains chromium (hexavalent compound).

-PROP 65-TERATOGENIC

WARNING: This product contains a chemical known to the state of California to cause birth defects or other reproductive har

CAS#	Chemical Name
	None

-PROP 65-CARCINOGENIC & TERATOGENIC

WARNING: This product may contain a chemical known to the stat California to cause cancer or birth defects or other reproduct

CAS#	Chemical Name
	None

MATERIAL SAFETY DATA SHEET Printed : 02/28/01
For Coatings, Resins and Related Materials
Revised : 11/30/99

SECTION I - PRODUCT INDENTIFICATION

Manufacturer: DEFT, INC. (CAGE CODE 33461)
17451 VON KARMAN AVENUE

IRVINE CA
92614

Information Phone: (949) 474-0400
Emergency Phone: (800) 424-9300
CHEMTREC Phone: 800-424-9300

roduct Class: TYPE I, CLASS C
rade Name : MIL-PRF-23377G (MIL-P-23377G)
roduct Code : 02Y040CAT
.A.S. Number: NONE

Hazard Ratings: Health - 3
none -> extreme Fire - 3
0 --> 4 Reactivity - 1

SECTION II - HAZARDOUS INGREDIENTS

			Exposure Limits				
		Weight	ACGIH		OSHA		VP
ngredients	CAS #	%	TLV	STEL	PEL	STEL	mm HG
LIPHATIC AMINE	80-05-7	5.	N.E.	N.E.	N.E.	N.E.	
	Contains Bisphenol A (CAS # 80-05-7) less than 55%.						
LIPHATIC AMINE	25154-52-3	< 5.	N.E.	N.E.	N.E.	N.E.	
	Contains Bisphenol A (CAS # 80-05-7) less than 55%.						
LIPHATIC AMINE	100-83-3	< 1.	N.E.	N.E.	N.E.	N.E.	
	Contains Bisphenol A (CAS # 80-05-7) less than 55%.						
LIPHATIC AMINE	140-31-8	5.	N.E.	N.E.	N.E.	N.E.	
	Contains Bisphenol A (CAS # 80-05-7) less than 55%.						
ec-BUTYL ALCOHOL	78-92-2	30.	100 ppm	N.E.	100 ppm	N.E.	12.5 @ 68F
8&10 AROMATIC HYDROCARBON	64742-95-6	< 5.	N.E.	N.E.	N.E.	N.E.	3 @ 68F
	Manufacturer recommends a PEL of 100 ppm.						
MINO SILANE ESTER	1760-24-3	< 1.	200 ppm	250 ppm	200 ppm	250ppm	
POXY RESIN HARDENER	90-72-2	< 5.	N.E.	N.E.	N.E.	N.E.	0 @ 70F
POXY RESIN HARDENER	71074-89-0	< 1.	N.E.	N.E.	N.E.	N.E.	0 @ 70F

THE ABOVE LISTED PRODUCTS ARE ON THE TSCA INVENTORY LIST.
ALSO ANY UNLISTED INGREDIENTS.

N.E. = Not Established

SECTION III - PHYSICAL DATA

oiling Range: 211 - 401 Deg. F
vap. Rate: 0.63 x n-Butyl Acetate
olatiles vol % 34.8 Wgt% 29.7

Vapor Density: Heavier than Air.
Liquid Density: Lighter than Water.
Wgt per gallon: 7.90 Pounds.
Spec. Gravity: 0.94838

ppearance: AMBER LIQUID WITH SOLVENT ODOR
V.O.C.: 281
OLUBILITY IN WATER: Insoluble PH: Not applicable
UTOIGNITION TEMPERATURE: No information found
ECOMPOSITION TEMPERATURE: No information found
ORROSION RATE: No information found
ISCOSITY: Thin liquid to heavy viscous material

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

lammability Class: IB Flash Point:72 F TCC LEL: 1.00% UEL: 9.80%

EXTINGUISHING MEDIA:

FOAM, ALCOHOL FOAM, CO2, DRY CHEMICAL, WATER FOG

SPECIAL FIREFIGHTING PROCEDURES:

Full fire fighting equipment with self-contained breathing apparatus and full protective clothing should be worn by fire fighters. Water may be used to cool closed containers to prevent pressure build-up, auto ignition or explosion.

UNUSUAL FIRE & EXPLOSION HAZARDS:

Keep containers tightly closed. Isolate from heat, sparks, electrical equipment and open flame. Closed containers may explode when exposed to extreme heat. Application to hot surfaces requires special precautions. During emergency conditions overexposure to decomposition products may cause a health hazard. Symptoms may not be immediately apparent.

SECTION V - HEALTH HAZARD DATA

PERMISSIBLE EXPOSURE LEVEL:

SEE SECTION II, HAZARDOUS INGREDIENTS.

EFFECTS OF OVEREXPOSURE:

INHALATION: Irritation of the respiratory tract & acute nervous system depression characterized by the following progressive steps: headache, dizziness, staggering gait, confusion, unconsciousness or coma.

SKIN AND EYE CONTACT: SKIN: Contact with the skin can cause irritation. Symptoms may be swelling, redness, and rash. EYES: Liquid, areosols, or vapors are irritating and may cause tearing, redness, and swelling accompanied by a stinging sensation.

SKIN ABSORPTION: Prolonged or repeated contact can cause moderate irritation, drying, and defatting of the skin which cause the skin to crack.

INGESTION: Acute: Can result in irritation and possible corrosive action in the mouth, stomach tissue and digestive tract. Vomiting may cause aspiration of the solvent, resultin in chemical pneumonitis.

HEALTH HAZARDS (ACUTE AND CHRONIC)
ACUTE: Vapors are irritating to eyes, nose, and throat. Inhalation may cause headaches, difficult breathing and loss consciousness.
CHRONIC: Prolonged contact will cause drying and cracking of skin due to defatting action. Skin sensitization, asthma or other allergic responses may develop. Potential for kidney an liver damage.

PRIMARY ROUTE(S) OF ENTRY:
TOPICAL (SKIN CONTACT): Yes
INGESTION (GASTRO-INTESTINAL): No
INHALATION (LUNGS): Yes

CARCINOGENICITY:
NTP?: NO, IARC MONOGRAPHS?: NO, OSHA REGULATED?: NO

MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE:
Asthma and any other respiratory disorders. Skin allergies, eczema, and dermatitis.

-FIRST AID:

INHALATION: Move to an area free from risk of further exposur. Restore breathing. Asthmatic type symptoms may develop and ma be immediate or delayed by several hours. Obtain medical attention.

SKIN: Remove contaminated clothing. Wash affected areas thoroughly with soap and water. Wash contaminated clothing thoroughly before reuse.

EYES: Flush with clean lukewarm water (low pressure) for at least 15 minutes, occasionally lifting eyelids. Obtain medical attention.

INGESTION: Do not induce vomiting. Do not give anything to an unconscious person. Obtain medical attention.

SECTION VI - REACTIVITY DATA

STABILITY: [ ] Unstable [x] Stable
HAZARDOUS POLYMERIZATION: [ ] May occur [x] Will not occur

-INCOMPATIBILITY
OXIDIZING MATERIALS AND STRONG ACIDS. EPOXY RESINS UNDER UNCONTROLLED CONDITIONS.

-CONDITIONS TO AVOID:
HIGH TEMPERATURES. EPOXY RESINS UNDER UNCONTROLLED CONDITIONS

-HAZARDOUS DECOMPOSITION PRODUCTS:
BY HIGH HEAT/TEMPERATURE: Carbon monoxide, carbon dioxide, and oxides of nitrogen.

SECTION VII - SPILL OR LEAK PROCEDURES

-STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED
Evacuate all non-essential personnel. Remove all sources of ignition (flame, spark sources, hot surfaces). Ventilate area Contain and remove with inert absorbent and non-sparking tool

-WASTE DISPOSAL METHOD:
Waste must be disposed of in accordance with federal, state, local environmental control regulations. Empty containers must be handled with care, due to product residue and flammable va
DO NOT incinerate closed containers.
ALSO SEE SECTION IV, V, VI, FOR OTHER PRECAUTIONS
EPA HAZARDOUS WASTE NUMBER/CODE: D001, F003, F00
HAZARDOUS WASTE CHARACTERISTICS:
IGNITABILITY: YES
CORROSIVITY: NO
REACTIVITY: YES

SECTION VIII - SPECIAL PROTECTION INFORMATION:

-RESPIRATORY PROTECTION:
A respirator that is recommended or approved for use in an organic vapor environment (air purifying or fresh air supplie is necessary. Observe OSHA regulations for respirator use. Ventilation should be provided to keep exposure levels below t OSHA permissible limits.

-VENTILATION:
Exhaust ventilation sufficient to keep the airborne concentrations of solvent vapors or mists below their respective TLV's must be utilized. Remove all ignition sources (heat, sparks, flame, and hot surfaces).

-PROTECTIVE GLOVES:
(continued on next page)

SECTION VIII - SPECIAL PROTECTION INFORMATION: (cont.)

PROTECTIVE GLOVES:
Protective gloves are recommended (cotton, neoprene rubber, polyethylene) to prevent skin contact.
EYE PROTECTION:
The use of safety eyewear is recommended, including splash guards or side shields, chemical goggles or face shields.
OTHER PROTECTIVE EQUIPMENT:
The use of long sleeve and long leg clothing is recommended. Remove and wash contaminated clothing before reuse.

SECTION IX - SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING:
Store in buildings designed to comply with OSHA 1910.106 Avoid storing near high temperatures, fire, open flames, and spark sources. Store in tightly closed containers. Store in well ventilated areas.
OTHER PRECAUTIONS:
Keep containers tight and upright to prevent leakage. Prevent prolonged breathing of vapors or spray mists. Prolonged over-exposure may cause an allergic reaction. Aviod contact with skin and eyes. Do not take internally. Do not handle until the manufacturers safety precautions have been read and understood. Wash hands before eating, smoking, or using washroom. Smoke in smoking areas ONLY.

*** TRANSPORTATION INFORMATION ***

APPLICABLE REGULATIONS: 49 CFR (YES); IMCO (NO); IATA (NO)
MILITARY AIR (AFR 71-4) (NO)
PROPER SHIPPING NAME: Paint UN NUMBER: UN-1263
REPORTABLE QUANTITY: Not applicable
HAZARD CLASS: Flammable liquid 3
THIS MATERIAL WHEN PACKAGED IN CONTAINERS OF 1 LITER OR LESS QUALIFIES AS PAINT IN LIMITED QUANTITY OF CLASS 3.
REQUIRED LABELS: Flammable liquid
U.S. POSTAL REGULATIONS: Not allowed to send via US POSTAL SERVICE.

*** DISCLAIMER ***

Information contained herein is furnished without warranty of any kind. Employers should use the information only as a supplement to other information gathered by them and must make independent determination of suitability and completeness of information from all sources to assure proper use of the materials and for the safety and health of their employees.

ACTUAL VOC DETERMINED PER EPA REFERENCE METHOD 24.

SECTION X - REGULATORY INFORMATION

-SARA 313:
This product contains the following toxic chemicals subject tc reporting requirements of section 313 of the Emergency Plannir and Community Right To Know Act of 1986 and of 40 CFR 372:

CAS#	Chemical Name	Percent by Weight
78-92-2	sec-BUTYL ALCOHOL	28.47

-PROP 65-CARCINOGENIC
WARNING: This product contains a chemical known to the state of California to cause cancer.

CAS#	Chemical Name
	None

-PROP 65-TERATOGENIC
WARNING: This product contains a chemical known to the state of California to cause birth defects or other reproductive ha:

CAS#	Chemical Name
	None

-PROP 65-CARCINOGENIC & TERATOGENIC
WARNING: This product may contain a chemical known to the stat California to cause cancer or birth defects or other reproduct

CAS#	Chemical Name
	None

Appendix A-2: DeSoto MSDS

MATERIAL SAFETY DATA SHEET — Printed : 07/09/97

Revised : 01/16/95

SECTION I - PRODUCT INDENTIFICATION

Manufacturer: COURTAULDS AEROSPACE
5430 SAN FERNANDO ROAD,
P.O.BOX 1800
GLENDALE CA 91209

Information Phone: (818) 240-2060
Emergency Phone: (800) 228-5635
CHEMTREC Phone: (800) 424-9300

Hazard Ratings: none -> extreme 0 ---> 4
Health - 2
Fire - 3
Reactivity - 0
Personal Protection - H

Product Class: EPOXY
Trade Name : 513X390 EPOXY POLYAMIDE PRIMER
Product Code : 513X390
MSDS ID No. : MS5711A00
D.O.T. Hazard Class : Flammable liquid — UN #: UN1263
Proper Shipping Name: Paint
Hazard Class 3 Packing Group 2
Reportable Quantity: See section VII

SECTION II - INGREDIENTS

Hazardous Ingredients	CAS #	Weight %	Exposure Limits ACGIH/TLV		Exposure Limits OSHA/PEL		VP mm HG
*METHYL ETHYL KETONE	000078-93-3	5.	200	ppm	200	ppm	70
		STEL=	300		300		
* ENE	000108-88-3	15.	50	ppm	100	ppm	23
		STEL=	- - - - -		150		
*XYLENE	001330-20-7	10.	100	ppm	100	ppm	6.6
		STEL=	150		150		
EPOXY RESIN	025036-25-3	25.	Undetermined				N/AP
*STRONTIUM CHROMATE	007789-06-2	20.	0.0005 As Cr	mg/M3	- - - - -	mg/M3	N/AP
		STEL=	- - - -		0.05 As Cr		
CHROMIC ACID,STRONTIUM SALT							
TITANIUM DIOXIDE @	013463-67-7	< 5.	10	mg/M3	10	mg/M3	N/AP
ISOPROPYL ALCOHOL	000067-63-0	< 5.	400	ppm	400	ppm	44
		STEL=	500		500		
TALC @	014807-96-6	15.	2	mg/M3	2	mg/M3	N/AP
METHYL AMYL KETONE	000110-43-0	< 5.	50	ppm	100	ppm	2.1

COURTAULDS AEROSPACE
Material Safety Data Sheet for: 513X390

SECTION II - (cont.)

*** ALL Ingredients in this product are listed in the T.S.C.A. Inventory.

@ -> These items are listed as required by 29CFR 1910:1200 because they appear on airborne contaminants list. However, in this product they are in fully encapsulated form and therefore are not hazardous to users under normal circumstances. If the cured product is sanded or ground so as to release respirable particles, suitable respiratory protection should be used.

* -> These items are subject to the reporting requirements of section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 and 40 CFR Part 372.

SECTION III - PHYSICAL DATA

Boiling Range: 175 - 300 Deg. F
Evap. Rate: Unavailable
Volatiles volume: 60.4 %

Vapor Density: Heavier than Air.
Liquid Density: Heavier than Water.
Wgt per gallon: 10.84 Pounds.
Spec. Gravity: 1.301

Appearance: YELLOW LIQUID, SOLVENT ODOR
V.O.C. (GR/L): 592 W/910X624&010X311 @4/4/1

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

F...mability Class: FLAMMABLE Flash Point: 22 F Setaflash LEL: Unknown

-EXTINGUISHING MEDIA:
Carbon dioxide, dry chemical or foam.

-SPECIAL FIREFIGHTING PROCEDURES:
Water spray may be ineffective. cool fire exposed containers with water. Fog nozzles are preferrable. Wear NIOSH/MSHA approved self-contained breathing apparatus and protective clothing to prevent contact with skin and eyes.

-UNUSUAL FIRE & EXPLOSION HAZARDS:
Vapors may accumulate in inadequately ventilated or confined areas. Vapors may form explosive mixtures with air. Vapors may travel long distances. Flashback or Flame to the handling site may occur. Closed containers may explode when exposed to extreme heat.

SECTION V - HEALTH HAZARD DATA

-PERMISSIBLE EXPOSURE LEVEL:
See section II (not established for product).

(cont.)

SECTION V - HEALTH HAZARD DATA (cont.)

-PERMISSIBLE EXPOSURE LEVEL: (cont.)
-EFFECTS OF OVEREXPOSURE:

MEK

EYES: MAY CAUSE BURNING, TEARING AND REDDENING. POSSIBLE TRANSIENT CORNEAL CLOUDING.
SKIN: PROLONGED EXPOSURE MAY CAUSE REDNESS, BURNING, DRYING AND CRACKING OF SKIN.
INHALATION: MAY CAUSE COUGHING, CHEST PAINS. THROAT IRRITATION. MAY CAUSE HEADACHES AND DIZZINESS; MAY BE ANESTHETIC AND MAY CAUSE OTHER CENTRAL NERVOUS SYSTEM EFFECTS. REVERSIBLE LIVER DAMAGE IS POSSIBLE AT HIGH DOSES.
INGESTION: MAY CAUSE DROWSINESS, DIZZINESS, AND NAUSEA.

TOLUENE

EYES: MAY CAUSE BURNING, TEARING AND REDDENING.
SKIN: PROLONGED EXPOSURE MAY CAUSE DRYING AND CRACKING OF SKIN, AND POSSIBLE DERMATITIS.
INHALATION: MAY CAUSE DIZZINESS, DROWSINESS AND FATIGUE. MAY CAUSE LIVER AND KIDNEY DAMAGE.
INGESTION: MAY CAUSE DROWSINESS, DIZZINESS AND NAUSEA.
EFFECTS OF LONG-TERM (CHRONIC) EXPOSURE
MAY CAUSE DISTURBANCE IN MEMORY, THINKING ABILITY, EMOTIONS AND COORDINATION.

THIS CHEMICAL IS ON THE LIST ENTITLED "CHEMICALS KNOWN BY THE STATE OF CALIFORNIA TO CAUSE REPRODUCTIVE TOXICITY".

XYLENE

EYES: MAY CAUSE BURNING, TEARING AND REDDENING.
SKIN: PROLONGED EXPOSURE MAY CAUSE DRYING AND CRACKING OF SKIN POSSIBLE DERMATITIS. THIS PRODUCT MAY BE ABSORBED THROUGH THE SKIN.
INHALATION: MAY CAUSE DIZZINESS, DROWSINESS AND FATIGUE. MAY CAUSE LIVER OR KIDNEY DAMAGE.
INGESTION: MAY CAUSE IRRITATION OF THE DIGESTIVE TRACT. SIGNS OF NERVOUS SYSTEM DEPRESSION (DROWSINESS, DIZZINESS, LOSS OF COORDINATION, AND FATIGUE). ASPIRATION HAZARD-THIS MATERIAL CAN ENTER LUNGS

(cont.)

SECTION V - HEALTH HAZARD DATA (cont.)

EFFECTS OF OVEREXPOSURE: (cont.)
DURING SWALLOWING OR VOMITING AND CAUSE LUNG INFLAMMATION AND DAMAGE.

BISPHENOL A / EPICHLOROHYDRIN RESIN

EYES: MAY CAUSE MECHANICAL IRRITATION.
SKIN: MAY CAUSE SKIN SENSITIZATION.
INHALATION: MAY CAUSE IRRITATION TO RESPIRATORY TRACT.
INGESTION: LOW ORDER OF ACUTE ORAL TOXICITY.

STRONTIUM CHROMATE *** C A R C I N O G E N *** BY NTP AND IARC

HEXAVALENT CHROMIUM COMPOUNDS ARE ON THE LIST ENTITLED "CHEMICALS KNOWN BY THE STATE OF CALIFORNIA TO CAUSE CANCER".

EYES: NO DATA.
SKIN: IRRITANT. POSSIBLE PAINLESS PENETRATING ULCERS OF SKIN. SENSITIZATION IN SOME INDIVIDUALS.
INHALATION: MAY CAUSE MUCOUS MEMBRANE IRRITATION AND PENETRATING ULCERS OF THE NOSE, PERFORATION OF CARTILAGINOUS NASAL SEPTUM. JAUNDICE AND KIDNEY DAMAGE REPORTED.
INGESTION: NO DATA.

ISOPROPYL ALCOHOL

EYES: IRRITANT.
SKIN: IRRITANT.
INHALATION: MAY CAUSE NOSE AND THROAT IRRITATION. MAY CAUSE FLUSHING, HEADACHE, DIZZINESS, MENTAL DEPRESSION, NAUSEA, VOMITING, NARCOSIS ANESTHESIA AND COMA.
INGESTION: MAY CAUSE HEADACHE, DIZZINESS, MENTAL DEPRESSION, NAUSEA, VOMITING, NARCOSIS, ANESTHESIA AND COMA.

MAK

EYES: MAY CAUSE BURNING, TEARING AND REDDENING.
SKIN: PROLONGED EXPOSURE MAY CAUSE DRYING AND CRACKING OF SKIN. POSSIBLE DERMATITIES.
INHALATION: MAY CAUSE DIZZINESS, DROWSINESS AND FATIGUE.
INGESTION: MAY CAUSE DROWSINESS, DIZZINESS AND NAUSEA.

(cont.)

COURTAULDS AEROSPACE
Material Safety Data Sheet for: 513X390

SECTION V - HEALTH HAZARD DATA (cont.)

-EFFECTS OF OVEREXPOSURE: (cont.)
-FIRST AID:
Eyes: Flush with water for 15 minutes. Get medical attention.
Skin: Wash with soap and water. Do not use solvents.
Remove contaminated clothing and wash before reuse.
If symptoms persist, get medical attention.
Inhalation: Remove to fresh air from exposure. Give artificial respiration or cardiopulmonary resuscitation (CPR) if breathing is difficult, get medical attention.
Ingestion: Get medical attention.

SECTION VI - REACTIVITY DATA

STABLITY: [ ] Unstable [x] Stable
HAZARDOUS POLYMERIZATION: [ ] May occur [x] Will not occur
-INCOMPATIBILITY
None recognized unless noted below.
-CONDITIONS TO AVOID:
None recognized unless noted below.
-HAZARDOUS DECOMPOSITION PRODUCTS:
Products of combustion are hazardous including carbon dioxide and carbon monoxide.

SECTION VII - SPILL OR LEAK PROCEDURES

-S PS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED
Protect from ignition. Wear air-supplied respirator for unventilated spill. Cover with absorbent material and scoop into container. Clean residue with a suitable solvent.
CERCLA RQ FOR MEK IS 5,000 LBS.
CERCLA RQ FOR TOLUENE IS 1,000 LBS.
CERCLA RQ FOR XYLENE IS 1,000 LBS.
CERCLA RQ FOR STRONTIUM CHROMATE IS 10 LBS.
-WASTE DISPOSAL METHOD:
When disposing of this material, ensure that it is packaged, stored, transported and otherwise managed in accordance with local, state and federal regulations.

SECTION VIII - SPECIAL PROTECTION INFORMATION:

-RESPIRATORY PROTECTION:
When spraying or applying in any circumstances likely to produce airborne level of hazardous ingredients in excess of TLV, use an organic vapor cartridge or air-supplied respirator.
-VENTILATION:
General ventilation to maintain vapors below TLV and PEL.
-PROTECTIVE GLOVES:
Solvent resistant gloves. During spray application, complete
(cont.)

SECTION VIII - SPECIAL PROTECTION INFORMATION: (cont.)

-PROTECTIVE GLOVES: (cont.)
skin protection is required.

-EYE PROTECTION:
Goggles or full-face shield.

-OTHER PROTECTIVE EQUIPMENT:
Avoid skin contact by use of other protective clothing. Safety shower, eye bath and washing facilities should be available.

SECTION IX - SPECIAL PRECAUTIONS

-PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING:
Keep container tightly closed. Isolate from heat, electrical equipment, sparks and flame. Do not store above 120 deg.F.

-OTHER INFORMATION :
Empty drums may contain explosive vapors. Do not cut, puncture or weld on or near drum.
Vapors of this product are heavier than air and may collect in low or confined areas.

Appendix B-1: Deft Data Tables

Sample Label	Cr Concentration (ppb) Deft		
	Initial [Cr] w/ particles	24-hr [Cr] no particles	48-hr [Cr] no particles
Deft1	511	431	442
Deft2	915	40	50
Deft3		118	123
Deft4	1,020	53	50
Deft5	3,080	141	152
Deft6	3,827	86	84
Deft7	102		26
Deft8	109		32
Deft9	45	19	17
Deft10	132	70	62
Deft11	208	57	36
Deft12	218	63	66
Deft13	554	55	248
Deft14	1,705	52	106
Deft15	117	166	301
Deft16	751	141	99
Deft17	77	2	5
Deft18	463	31	31
Deft19	665	43	49
Deft20	77	44	31
Deft21	143	45	42
Deft22	273	47	49
Deft23	152	41	40

Appendix B-2: DeSoto Data Tables

Sample Label	Cr Concentration (ppb) Deft		
	Initial [Cr] w/ particles	24-hr [Cr] no particles	48-hr [Cr] no particles
DeSoto1	147	94	1
DeSoto2	149	157	58
DeSoto3	224	99	140
DeSoto4	1,810	171	
DeSoto5	6,449	148	
DeSoto6	4,728	154	303
DeSoto7	145	127	118
DeSoto8	534	178	332
DeSoto9	1,496		863
DeSoto10	274	69	73
DeSoto11	450	208	282
DeSoto12	46		26
DeSoto13	79		43
DeSoto14	1,269		149
DeSoto15	123	35	32
DeSoto16	590	70	71
DeSoto17		159	189
DeSoto18	160	79	89
DeSoto19	768	112	64
DeSoto20	883	143	141
DeSoto21	1,084	214	205
DeSoto22	944	80	185
DeSoto23	1,391	97	121
DeSoto24	202	39	42
DeSoto25	294	42	48
DeSoto26	566	70	68
DeSoto27	881		73
DeSoto28	1,916	87	103
DeSoto30	1,296	85	
DeSoto31		146	137
DeSoto32		122	65

Appendix C: Residence Time t Test

$H_o: \mu_{Deft24} = \mu_{Deft48}$

$H_a: \mu_{Deft24} \quad \mu_{Deft48}$

t-Test: Two-Sample Assuming Equal Variances

	Deft 24-hr [Cr] no particles	*Deft 48-hr [Cr] no particles*
Mean	83.1	99.3
Variance	8136.2	11597.3
Observations	21.0	21.0
Pooled Variance	9866.8	
Hypothesized Mean Difference	0.0	
df	40.0	
t Stat	-0.5	
P(T<=t) one-tail	0.3	
t Critical one-tail	1.7	
P(T<=t) two-tail	0.6	
t Critical two-tail	2.0	

$H_o: \mu_{DeSoto24} = \mu_{DeSoto48}$

$H_a: \mu_{DeSoto24} \quad \mu_{DeSoto48}$

t-Test: Two-Sample Assuming Equal Variances

	DeSoto 24-hr [Cr] no particles	*DeSoto 48-hr [Cr] no particles*
Mean	98.4	112.5
Variance	5330.7	9591.1
Observations	44.0	44.0
Pooled Variance	7460.9	
Hypothesized Mean Difference	0.0	
df	86.0	
t Stat	-0.8	
P(T<=t) one-tail	0.2	
t Critical one-tail	1.7	
P(T<=t) two-tail	0.4	
t Critical two-tail	2.0	

Appendix D: Particle Count Contributed by Painting

Particles/ml Contributed by Painting

Sample Label[1]	Bin Size (µm)														
	0.5	1	2	3.5	5	6.5	8	9.5	11	12.5	14	15.5	17	18.5	20
DeSoto1-3	1,395	38,059	2,118	74	-	-	-	-	-	-	-	-	-	-	-
DeSoto4-6	-	30,046	27,013	6,860	1,731	728	375	205	118	75	42	40	29	25	90
DeSoto7-9	-	43,368	12,668	1,928	431	222	122	72	47	27	23	14	6	5	-
DeSoto10-11	-	24,930	1,798	427	162	115	75	61	42	23	22	16	17	15	14
Deft1-3	-	26,488	28,758	1,221	446	287	173	113	84	64	42	25	19	18	83
Deft4-6	-	28,443	10,209	4,659	2,255	1,529	1,103	795	595	453	340	254	176	140	476
Deft-none[2]	-	26,488	28,758	1,221	446	287	173	113	84	64	42	25	19	18	83
Deft7-9	-	39,980	6,388	434	149	99	57	41	24	20	16	9	5	5	12
DeSoto12-14	-	32,651	27,489	2,597	192	39	-	-	-	-	3	2	5	1	17
DeSoto15-16	-	32,792	25,196	2,997	296	72	18	4	1	2	4	1	1	2	4
DeSoto18-20	-	30,114	31,853	3,426	435	144	71	41	30	18	18	12	16	13	68
Deft10-12	-	49,380	1,428	181	40	16	5	6	6	3	1	-	1		-
Deft13-14	-	41,907	19,651	641	190	105	64	39	28	17	11	10	8	6	17
Deft15-17	-	50,490	4,331	126	-	-	-	-	-	-	-	10	8	8	80
Deft18-20	-	50,535	4,494	571	160	75	39	24	18	10	7	5	3	2	2
Deft21-23	-	45,688	15,253	484	130	69	40	31	26	18	17	13	12	11	60
DeSoto21-23	-	36,615	22,480	2,054	243	64	29	24	9	8	8	5	6	2	10
DeSoto24-26	-	40,518	13,085	1,604	247	89	25	13	4	3	1	1	-	-	-
DeSoto27-28	-	39,046	18,254	1,303	43	-	-	-	-	-	-	-	-	-	-
DeSoto30	-	27,482	33,648	4,258	428	94	31	3	-	-	4	2	4	4	-

[1]Note: The sample label spans the corresponding manufacturer and concentrations identified in Appendix B-1 and B-2 (i.e. Deft1-3 corresponds to Deft1, Deft2, and Deft3 sample concentrations).
[2]Note: No corresponding sample concentrations are available for this particle count.

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Vita

Major David A. Kauth was born on [redacted] in Dayton, Ohio. He graduated from Chaminade-Julienne High School in Dayton, Ohio in May 1984. He received an appointment from Congressman Tony P. Hall, and entered the Air Force Academy on July 6, 1984 and graduated with a Bachelor of Science degree in Biology on June 1, 1988. In May 1989, he received orders to Travis AFB, California, serving as Assistant Chief, Bioenvironmental Engineering. He identified a portable oxygen cylinder manufacturing design flaw—resulting in removal of polychlorinated biphenyl (PCB) contaminated cylinders used in aircraft throughout the Department of Defense. In October 1991 he earned coveted California State Certification for the base drinking water testing laboratory. In May 1992 he was assigned to the 97th Medical Group, Altus AFB, Oklahoma serving as Chief, Bioenvironmental Engineering. In August 1993, his duties were expanded to assist the 97th Logistics Group in setting up a "small base" prototype for a new Air Force system designed to control the issue and tracking of hazardous materials used on base–known as the Hazardous Materials Pharmacy. In 1994, he was sent to Sheppard AFB, Texas to receive training as a Medical Readiness Officer. Upon completion of the course in November 1994 he was appointed Chief, Medical Readiness, 97th Medical Group, Altus AFB, Oklahoma. From December 1994 to March 1995, he deployed to Cuba in support of Operation Sea Signal-where he provided sole industrial hygiene support for the 7000 Joint Task Force personnel and 23,000 Cuban and Haitian migrants. In July 1995 he was assigned to one of the largest industrial hygiene programs in the Air Force as Chief, Industrial Hygiene Surveillance, 74th Aerospace Medicine

Squadron, Wright-Patterson AFB, Ohio. In August 2000, he entered the Graduate School of Engineering and Management, Air Force Institute of Technology. Upon graduation he will be assigned to Langley AFB, Virginia as the Chief, Bioenvironmental Engineering. Major Kauth's military decorations include the Airman's Medal, the Air Force Meritorious Service Medal, the Air Force Commendation Medal with two oak leaf clusters, the Joint Meritorious Unit Award, the Air Force Outstanding Unit Award with two oak leaf clusters, the National Defense Service Medal, and the Humanitarian Service Medal. He is also a graduate of the Air Force Squadron Officers School in-residence program.

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14. ABSTRACT
The use of chromate as a corrosion inhibitor in primer paint is an essential component for the protection of aluminum-skinned aircraft and the primary source of hexavalent chromium (Cr (VI)) exposure to USAF aircraft painters. The objective of this research was to quantify the dissolution of chromate from freshly sprayed paint particles into a simulated lung fluid (SLF). Two primer paints were sprayed with a paint spray gun to generate overspray particles for collection into impingers filled with SLF. Particles were allowed to soak in SLF for 24 and 48 hours and then the particles were removed by centrifugation. The remaining Cr (VI) dissolved in the SLF was then compared to the initial Cr (VI) concentration with particles. The results indicate that the dissolution of Cr (VI) into SLF is hindered by the paint. Also, the results indicate that the amount of Cr (VI) dissolved into SLF from the paint particles is not significantly different between the two paints tested or between the 24- and 48-hour resident times. This study suggests that Cr (VI) in paint particles is less bioavailable than Cr (VI) in other particles such as dust or mist.

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