AN ASSESSMENT OF LEAD EXPOSURES IN THREE RADIATOR REPAIR SHOPS

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ABSTRACT

Because of the high potential for lead poisoning in the radiator repair industry and the need for more complete exposure data, an assessment of worker exposures to lead was conducted in a sample of radiator repair shops. Area and personal sampling for airborne and surface lead was conducted in three Cincinnati radiator shops. A total of 129 air samples and 126 wipe samples were collected. The highest air concentrations were found near the repair stations where mechanics work with molten lead-based solder. The mean eight-hour TWA lead exposure for mechanics was 15.2 $\mu g/m^3$ (SD=33.3) with a range of 0.9 to 157 $\mu g/m^3$. The two shops which used local exhaust ventilation systems were found to have effectively controlled worker exposures to airborne lead. Personal time-weighted exposures averaged less than one-fifth the OSHA PEL (50 $\mu g/m^3$) in these shops. However, exposures in the third shop, in which there was no local ventilation, were frequently above the PEL.

These survey results also indicate that sources of exposure other than airborne lead, such as hand, facial, and work surface contamination, may make a significant contribution to the total lead exposure. Lead contamination on work surfaces in these shops was found as high as 500,000 $\mu g/m^2$. Lead dust was also found in lunch areas, on hands of workers (both before and after washing), on street shoes, and in personal vehicles. As with airborne lead, the individual hand, facial, and surface lead levels varied widely throughout the surveys.

These results are similar to those found in other studies of radiator repair shops and confirm the potential for excessive lead exposures of radiator mechanics as well as their families. Lead poisoning is entirely preventable--if actions are taken to eliminate exposures to lead. These should include: the installation of an effective local exhaust ventilation system; the mandatory use of protective equipment, such as respirators (until exposures are below the PEL), and gloves and uniforms which are replaced daily; a strict adherence to personal and environmental hygiene; an enforced prohibition of eating and smoking in all lead-contaminated areas; the implemention of routine environmental and medical monitoring programs; and training to increase the awareness of the problems associated with lead use. Radiator shop owners should recognize and meet their inherent obligation to protect not only their employees from lead poisoning but also the employees' families.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 Introduction

While lead poisoning is usually considered one of the oldest recognized occupational diseases, exposure to lead continues to occur in many industries. Recent studies suggest that the use of solder for the assembly and repair of automotive radiators is a common source of exposure to lead that has received little public recognition.[1-3]

There are an estimated 10,000 radiator repair shops in the United States, employing an average of four workers each.[4] Exposure to inorganic lead during radiator repair is by the inhalation of lead fumes and lead oxide dusts generated by soldering, burning, grinding, and brushing activities; accidental ingestion may also result from lead contamination of work surfaces, food, and a worker's hands, face, and clothing. Airborne lead levels as high as 500 $\mu g/m^3$ (10 times greater than the Occupational Safety and Health Administration [OSHA] workplace limit) have been reported in radiator shops.[5] Evaluations by the National Institute for Occupational Safety and Health (NIOSH) from 1979 to 1990 in radiator shops indicated that 68% of the workers sampled had lead exposures exceeding the OSHA standard.[3] Past studies also indicate that blood lead levels (BLLs) of shop employees are substantial. For example, among 56 radiator repair mechanics in the Boston area, 80% had BLLs greater than 30 micrograms per deciliter ($\mu g/dL$), and 16% had BLLs greater than 50 $\mu g/dL$.[2]

To minimize health risks to workers exposed to lead, OSHA promulgated the Lead Standard in 1978 which includes provisions for environmental sampling, biomonitoring, medical removal, worker education, personal protection, and engineering controls.[6] However, radiator repair shops are generally small business operations with limited resources, and owners and employees may be poorly informed about hazardous substances, conditions in their shops, or occupational health guidelines. Further, the tasks of assisting and inspecting small businesses are frequently not assigned a high priority by regulatory agencies. For example, in California in 1986, only 1.4% of radiator mechanics worked in shops where environmental monitoring was ever done; only 7.9% of the shops surveyed performed any routine blood monitoring.[7]

Because of this high potential for lead poisoning in the radiator repair industry and the need for more complete exposure data, an assessment of worker exposures to lead was conducted in three radiator repair shops in the Cincinnati area. The results of these descriptive investigations are reported herein.

2.0 Background

2.1 Toxicity of Lead

Lead can enter the body in two ways. Lead can be inhaled (breathed) when lead dust or fumes are in the air; inhalation of lead particles is generally the most important source of lead exposure in the workplace. Lead can also be ingested (swallowed) following hand-to-mouth contact with lead-contaminated skin, food, beverages, tobacco products, or clothing.

Once lead enters the body, the frequency and severity of medical symptoms increase with the concentration of lead in the blood, although the specific blood lead level (BLL) associated with symptoms of lead toxicity varies from one person to another. Overt symptoms of lead poisoning in adults generally begin at BLLs between 60 and 120 μg/dL. Neurologic, hematologic, and reproductive effects, however, may be detectable at much lower levels, and the World Health Organization (WHO) has recommended an upper limit of 40 μg/dL for occupationally exposed males.[8] The mean BLL for U.S. men in 1976 through 1980 was 16 μg/dL; however, with the ubiquity of lead-free gasoline and reduced lead in foods, the 1991 average BLL of U.S. men will probably drop below 9 μg/dL[9-10]

2.1.1 Acute Effects

Common symptoms of acute lead poisoning are loss of appetite, metallic taste, nausea, vomiting, stomach cramps, constipation, fatigue, insomnia, moodiness, headache, joint or muscle aches, anemia, and loss of sexual drive. Severe health effects of acute lead poisoning include damage to the nervous system, including wrist or foot drop, tremors, and convulsions or seizures. The effects of lead on the nervous system may not be reversible.[6,11]

2.1.2 Chronic Effects

Chronic exposure to lead results in an accumulation of lead in the body over time. Lead accumulates primarily in the soft tissue and bones, with the highest accumulation in the liver, kidneys, and cortical bone; elimination is slow. Stored lead may be released into the blood gradually over time or rapidly following some physiological event such as illness or pregnancy. Chronic adverse effects include impaired heme synthesis, hypertension, severe peripheral neuropathy with paralysis of the muscles of the wrists and ankles, encephalopathy, proximal kidney tubule damage, decreased kidney function, and chronic kidney disease. Long term exposure can also result in sterility in men and decreased fertility and abnormal menstrual cycles in women. There is equivocal evidence of miscarriage, and stillbirth in women who were exposed to lead or whose husbands were exposed. Lead can also penetrate the placental barrier, resulting in damage to the developing fetus; children born of parents either of whom were exposed are more likely to have birth defects, mental retardation, and behavioral disorders.[6,11,12]

2.2 Evaluation Criteria and Regulations

2.2.1 OSHA

In 1978, OSHA promulgated a comprehensive standard regulating occupational exposure to inorganic lead in general industry.[6] Under this standard, the permissible exposure limit (PEL) is 50 $\mu g/m^3$ calculated as an eight-hour time-weighted average (TWA); the action level (AL) is 30 $\mu g/m^3$.

The OSHA Lead Standard requires that all lead-using companies conduct air sampling at least once to establish baseline lead exposures.[6] The employer must collect representative, full-shift personal samples for each job with potential lead exposure, selecting the employee(s) judged to be at greatest risk of exposure. This "initial determination" determines the degree of lead exposure and is the key to other requirements in the Standard, such as blood-lead testing, further air monitoring, and engineering controls. Air monitoring must be repeated any time there is a change in production, process, control, or personnel, which may result in new or additional exposures to lead. At a minimum, all lead-using companies must have a written record of the results of the initial determination, and must maintain these records for at least 40 years.

If lead exposures are at or above the AL but below the PEL, the employer is required to (a) notify their employees in writing of the air monitoring results; (b) repeat air monitoring every six months until two consecutive measurements, taken seven or more days apart, are below the AL; (c) establish a medical surveillance program if workers are exposed at or above the AL for more than 30 days each year; and (d) provide employees with information and training on the hazards of lead use and the general provisions of the Lead Standard.

If worker exposures exceed the PEL, OSHA also requires the employer to (a) have a written compliance program for controlling lead exposures; (b) reduce lead exposures to below the PEL, by installing engineering controls, such as local exhaust ventilation; (b) provide employees with respiratory protection, free of charge, and ensure its use until exposures are reduced below the PEL; (c) provide clean work clothing, change room, showers, and a separate lunch room, all at no charge; (d) prohibit eating, drinking, and smoking in areas where lead levels exceed the PEL; and require hand and face washing before eating, drinking, smoking, or applying cosmetics. OSHA also requires that air sampling be repeated every three months if air lead levels are above the PEL, or every six months if below the PEL but above the AL. Sampling must be repeated at these frequencies until at least two consecutive samples, taken at least seven days apart, are below the AL, at which time the employer may discontinue air monitoring, unless a process or personnel change occurs which may result in new or additional exposure to lead.

Blood-lead testing is required for all employees working in any areas exceeding the AL. The frequency of subsequent blood-testing and any medical removal provisions are determined by an individual's BLL. In cases where the BLL exceeds 40 μg/dL of whole blood, the employee must be notified in writing, provided a medical examination and consultation, and the BLL must be monitored every 2 months. Workers with a single BLL exceeding 60 μg/dL or an average (of three tests) BLL greater than 50 μg/dL must be immediately removed from lead exposure until the BLL drops below 40 μg/dL. The employee must continue to receive full salary and benefits during this removal, for up to 18 months.[6]

2.2.2 NIOSH

The National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL) for lead in air, initially established in 1978, is less than 100 $\mu g/m^3$ as a TWA for up to 10 hours per day such that the worker's BLL remains below 60 $\mu g/dL$.[13] NIOSH is presently reviewing the data on the health effects of lead to determine whether the REL needs revision.

2.2.3 ACGIH

The American Conference of Governmental Industrial Hygienists (ACGIH) recommends a Threshold Limit Value (TLV) of 150 $\mu g/m^3$ as a time-weighted average for a normal eight-hour workday. There is no short-term exposure limit (STEL) for lead. The ACGIH Biological Exposure Index (BEI) for lead in blood in 50 $\mu g/dL$. Both the TLV and BEI for inorganic lead, last adopted in 1986 and 1987, respectively, are currently under study for possible revision.[14]

2.2.4 HUD

Presently, there are no Federal standards for surface contamination in occupational environments but the U.S. Department of Housing and Urban Development (HUD) has established interim regulations which require that surface lead contamination (as measured by wipe sampling with commercial wipes pre-moistened with non-alcohol wetting agents) be less than 200 $\mu g/ft^2$ (2,160 $\mu g/m^2$) on floors, 500 $\mu g/ft^2$ (5,400 $\mu g/m^2$) on window sills, and 800 $\mu g/ft^2$ (8,640 $\mu g/m^2$) in window wells in residential housing following removal of lead-based paint.[15] These guidelines were primarily based on previous standards established in Massachusetts and Maryland to help prevent lead poisoning of young children in residences. These criteria were not based on health risk assessment, but were empirically established as feasible limits for clearance following final cleanup during lead-paint abatement. However, HUD recommends the use of these criteria until they are revised based on additional information.

It should be recognized that the length of exposure, the potential for contact with surface contamination, and the frequency of hand-to-mouth contact is probably much greater in the residential environment than in the occupational workplace. Therefore, direct comparison between surface lead concentrations in the workplace and the HUD standards may not be appropriate but should provide some reference for assessing the degree of lead contamination.

2.3 Past Studies of Radiator Repair Workers

In general, BLLs in radiator repair mechanics are less than levels routinely found in high risk occupations such as lead smelting, storage battery manufacturing, or metal foundries (where levels occasionally exceed 100 $\mu g/dL$). They do, however, exceed those found in adult males in the general population (13 to 15 $\mu g/dL$), and more than 20% of radiator repair mechanics are estimated to have BLLs of 50 $\mu g/dL$ or greater, the level which triggers medical removal.[3,16]

Lussenhop et al., measured airborne and blood lead levels in 53 workers from 30 repair shops in the Minneapolis-St. Paul area in 1986.[1] On average, each shop in the study had 4 mechanics and repaired 36 radiators per week. The mean area lead concentration was 40 $\mu g/m^3$ (standard deviation [SD]=60) and the mean personal air lead concentration was 113 $\mu g/m^3$ (SD=20) averaged over 3 to 6 hours. The mean blood lead level was 31.7 $\mu g/dL$ (SD=12.6); 17 (32%) workers had levels $\geq$ 40 $\mu g/dL$. No single job or worker characteristic was a good predictor of elevated blood lead; volume of radiator repair and shop age were associated with increased blood lead levels. Environmental data did not correlate well with blood lead levels, according to the authors.

Goldman et al., surveyed radiator mechanics in 27 shops in Boston.[2] Environmental samples taken in 5 shops indicated mean personal air concentrations ranging from 8 to 160 $\mu g/m^3$ (sampling duration not specified). Fifty-six mechanics had a mean blood lead level of 37.1 $\mu g/dL$ (SD=13.8); 39% of these mechanics had levels higher than 40 $\mu g/dL$, and 7% were above 60 $\mu g/dL$. Regression analysis showed that the number of repair stations (i.e., level of work activity) was the variable most significantly associated with increased blood lead levels.

In 1988, 83 automotive repair workers with BLLs > 25 $\mu g/dL$ were reported to state health departments in seven states that collaborated with NIOSH in maintaining registries of elevated BLLs in adults.[3] In 22% of these persons, BLLs were > 50 $\mu g/dL$. Among automotive repair workers for whom a job category was specified, radiator repair work was the principal source of lead exposure. The authors further stated "in general, environmental monitoring and medical surveillance for lead exposure in radiator repair workers is inadequate."

An analysis of air lead concentrations measured during OSHA inspections in California radiator repair shops indicated 62% (23 of 37) samples exceeded 50 $\mu g/m^3$; lead exposures as high as 150 $\mu g/m^3$ were measured.[17,18] The authors suggest that exposure violations may occur in small businesses such as radiator shops largely because of OSHA's higher priority to enforce compliance in more recognized high lead industries such as lead smelters, battery manufacting plants, and brass foundries.

In establishing the PEL for lead, OSHA recognized that the particle size distribution of lead aerosols would affect the concentration of lead in the blood of exposed workers.[6] A pharmacokinetics model adopted by OSHA to predict the air lead-blood lead relationship included the assumption that inhaled lead aerosols deposit in different regions of the respiratory tract, depending primarily on particle size (generally, small particles in the lungs and large particles in the gastrointestinal tract).[19] Further, the site of deposition would largely determine the subsequent degree of absorption and metabolism of the particle. Using particle size information primarily collected from the lead battery industry, the model assumed that "the first 12.5 $\mu g/m^3$ of lead in the air of lead battery plants is generally composed of small particles, but that as air lead concentrations rise beyond that minimal level, all additional air lead is present in large particles." In the model, small particles were those less than 1 μm aerodynamic diameter.[19] Although the empirical evidence was limited, OSHA considered this distribution to be the best available and it was subsequently used in selecting a PEL which was applicable in all lead-user industries. This distribution also came closest to approximating the desired health goal of $\leq$ 40 $\mu g/dL$ for all workers and was also considered to be feasible.[6] (Interestingly, although OSHA recognized the need to address particle size distribution in predicting blood lead levels, it did not incorporate similar considerations into its requirements for environmental compliance, i.e., size-selective sampling). Subsequent studies in various lead industries have included particle sizing with comparisons of measured particle size distributions to that assumed in the OSHA model.[20,21]

Hodgkins et al., measured particle size distributions in different work areas of 2 battery manufacturing plants.[20] Mass median diameters (MMDs) were all greater than 10 μm (geometric standard deviations [GSDs] ranging from 2.2 to 5.2). In addition, this study presented empirical evidence that, within the lead battery industry, air lead concentration above a certain level is indeed contributed to by particles with aerodynamic diameters $\geq$1 μm, but at a lower concentration than used in the OSHA model (1.0 $\mu g/m^3$ versus 12.5 $\mu g/m^3$). These results would substantially lower the blood lead levels predicted for a given air lead concentration and therefore suggests that the OSHA PEL is more conservative than needed to achieve the targeted distribution of blood lead levels in the lead industries.

Froines et al., investigated the particle size distribution of lead aerosols in a brass-bronze foundry, as determined by general area samples.[21] Large differences in aerosol distributions were measured between different process areas (MMDs ranging from 2.1 to 12.5 μm with GSDs varying from 2.4 to 15.7). Using these particle size distributions, the predicted proportion of workers with blood lead concentrations above 40 $\mu g/dL$ was over 78% in some work areas, compared to only 50% when using the distribution assumed in the OSHA model. The authors therefore suggest that, because varying size distribution will significantly affect blood level distribution, actual size distributions should be taken into consideration whenever assessing worker protection.

While measurement of airborne lead concentrations is the primary procedure for assessing worker exposures and employer compliance with the OSHA PEL, some investigators have recognized that poor personal hygiene habits of industrial workers can contribute to lead exposure through unintentional ingestion.[22-24] Contaminated food, tobacco products, skin, and clothing may be potential contributors of lead absorption through ingestion. In fact, the Lead Standard includes administrative and work practice controls intended to reduce lead uptake by ingestion. However, the Standard offers no strategy or procedure for the quantitative assessment of this route of exposure. The measurement and evaluation of the potential sources of ingestion or dermal contact from work surface and personal contamination, therefore, have been relatively ignored.

Chavalitnitikul performed a laboratory evaluation of wipe testing methods for lead dust.[22] Wipe materials included moistened filter paper, commercially-available pre-moistened paper towels, adhesive tape, and adhesive paper labels. Results indicated that recoveries of up to 90% can be obtained with good repeatability using moist paper on non-porous surfaces. Adhesive materials provided optimum recovery on porous surfaces. An accurately defined sampling area was suggested to be critical for reliable measurements.

Chavalitnitikul subsequently measured lead surface contamination (i.e., on workers' hands, and face and on work surfaces) during a follow-up field survey in a lead battery plant.[23] Personal contamination samples were taken using a commercially available paper towel pre-moistened with benzalkonium and alcohol. Each participant was instructed to wipe his/her hands thoroughly; the investigator wiped each participant's face. Hand measurements of plant workers were from 40 to 90 times greater than control workers. Mean concentrations of facial measurements (not taken on control workers) varied significantly by work area (i.e., "dustiness"). The highest values for facial and hand wipes were 603 and 14,023 μg/sample, respectively.

Que Hee et al., investigated various sample collection and analytical procedures for optimizing recovery of lead from contaminated surfaces and inhabitants in residential housing.[24] Several different wiping materials, rinse solutions, and collection procedures were used to assess personal surface contamination. The authors concluded that repetitive wipes by the investigator (versus the test subject) using a commercial "wet-wipe" (Wash n' Dri™ Moist Towelettes) was the most efficient method after 5 wipes (89% cumulative absolute efficiency) and that multiple wipes (>2) were necessary for precise results. Also, battery-operated sampling pumps operated at different flow rates with various sampling trains were used to compare collection efficiencies for loosely-applied house dusts from various surfaces. A sampler operated at 2.0 Liters per minute (Lpm) with Tygon™ tubing at a 45° angle to the surface was the most efficient and reproducible method for collecting loose dusts from surfaces (≈75% relative recovery after 2 passes). However, the authors cautioned that this method is much less successful when sampling surfaces with greasy dusts; handwiping materials and techniques were suggested in this situation.

2.4 Description of a Radiator and the Repair Process

A radiator is a water-filled set of tubes commonly used in automobiles, trucks, or industrial equipment to cool generated heat from engines. Water carries heat from the engine to tubes in the radiator, where moving air cools it. An automotive radiator consists of a series of copper or aluminum tubes (called the "core"), a header (with a water-fill inlet) on top of the core which seals the core, tank(s) for storing water, and brackets for attachment to the vehicle. Radiators may become damaged by corrosion, excessive pressure, clogged tubes, or collision.

Damaged radiators are either removed from cars or trucks off-site and brought into the shop for repair or a vehicle may be driven to the shop where the radiator is removed by a radiator mechanic. Generally, the mechanic first cleans grease and dirt from the radiator by submerging it into a tank containing a heated caustic solution and/or spraying it with water. The radiator is then usually mounted on a lift device that allows the mechanic to raise, lower, and rotate the radiator while being repaired. The radiator lift is positioned over a water-filled test tank into which the radiator (while pressurized) is submerged to test for leaks; the test tank also catches any excess solder during repairs. Minor leaks in the core and tank(s) are generally patched with solder (a standard 40% tin-60% lead alloy) whereas larger repairs require the radiators to be disassembled (or "torn down") by melting the solder joints between the tank, side brackets, and core using gas (e.g., oxygen-acetylene or natural gas-oxygen) torches. Sometimes, a wire brush is used to clean solder from the joints during heating. The tank is then cleaned (generally by abrasive blasting in an enclosed sand blaster), patched, or replaced. The tank and side brackets are then reattached to the core with solder. Grinding may be necessary to smooth metal parts and joints. The repaired radiator is then retested for any leaks.

The primary source of exposure to lead during radiator repair is generally considered to be the inhalation of airborne lead fumes generated during burning and soldering metal joints. Secondary sources include the inhalation and/or ingestion of lead dusts resulting from grinding or wire brushing.

Radiator repair work is generally seasonal since most radiator problems manifest when higher ambient temperatures require the engine cooling system to operate more frequently and efficiently. Repair shops therefore tend to be busiest during May through September.

2.5 Study Objectives

Air lead concentrations in various industrial environments, including radiator repair shops, vary with job, area, work volume, and control practices. Air concentrations are often reported in excess of the OSHA PEL.[1-3,5,6,16-18,20,21,25,26] Further, the need for determining particle size distributions in workplaces where lead exposures occur has been suggested.[19-20] While surface and personal contamination of lead have been acknowledged, particularly in the residential community, few studies have quantified these possible sources of lead ingestion among among workers.[21-23]

This project was designed to be a descriptive study of lead exposures in a sample of radiator repair shops in the Cincinnati area. The specific objectives included: 1) to determine the concentrations of inorganic lead as measured in the air, on workers' skin, and on work surfaces in these shops; 2) to determine the particle size distributions of lead aerosols; 3) to evaluate the degree of compliance with the OSHA exposure limits and monitoring requirements specified under the OSHA Lead Standard (29 CFR 1910.1025); 4) to evaluate the feasibility of various field sampling methodologies; and 5) to assess the need for improvements in the level of exposure monitoring, medical surveillance, work practices, control technology, and worker education. Additionally, information from this study may be used by health professionals, lead-industries, and others for determining the needs and direction of future research.

3.0 Methods

3.1 Sample Size

This was designed to be a descriptive study in which the primary criteria for determining the number of shops surveyed were available resources and logistics. Recognizing that repair work may be quite intermittent, the survey duration at any shop was chosen such that periods of typical repair work would most likely be observed and sampled. Therefore, four to five consecutive days of sampling were chosen for each shop surveyed. With consideration to time, manpower and financial limitations, a sample size of three radiator shops was subsequently judged to be feasible.

3.2 Facility Selection

For this study, a radiator shop was defined as an establishment in which the primary business was the repair of radiators. Radiator repair companies located within the greater Cincinnati area were identified from the 1990-91 Cincinnati and Hamilton County Consumer Yellow Pages (Cincinnati Bell, Donnelley Directory). Fifty percent of the 40 businesses listed under "Radiators-Automotive" were chosen by random selection and these companies were then sent a letter of introduction explaining the study purpose, benefits and survey logistics and requesting information about solder usage, repair volume, number of workers, engineering controls, and other shop information (see Appendix A). A follow-up letter was sent to any non-respondents (Appendix B). From those respondents which used lead solder and repaired radiators on a regular basis, three shops were selected for field surveys based on the following criteria: highest estimated work volume, greatest number of full-time repair mechanics, and geographic location. This target group of shops was subsequently contacted by letter (Appendix C) and by telephone to schedule a sampling survey.

3.3 Air Sampling

Personal and area air samples were collected following NIOSH Sampling and Analytical Method 7082 (collection on 37 mm diameter, 0.8 μm pore size, mixed cellulose ester (MCE) filters) using personal air samplers (Gillian®) calibrated at 2.0 liters per minute (Lpm), and analyzed using flame atomic absorption spectrophotometry (AAS) (see Appendix D).[27] The actual limit of detection (LOD) for different groups of sample filters from this study ranged between 1.0 to 2.0 μg/filter; the limit of quantitation (LOQ) ranged between 3.3 to 4.5 μg/filter. Any samples with non-detectable results using Method 7082 were reanalyzed using Method 7105 (graphite furnace atomic absorption spectrophotometry) which has a higher analytical sensitivity (LODs ranged between .03 to .06 μg/filter; LOQs between .09 to .19 μg/filter) (see Appendix E).[27]

Personal breathing zone (PBZ) samples were collected on all radiator mechanics at each shop. PBZ sampling on each mechanic started as soon as possible after he arrived at the shop and ended immediately prior to his leaving (or, in a few cases, at the end of radiator repair work if no further soldering was planned). Additionally, some short-term samples were obtained only for the duration of a single radiator repair. In addition, area samples were collected at each active radiator repair station, in the shop area away from the repair stations, in the shop office, in the lunch area (if separate from the office), and in the ambient outdoor air. A minimum of four field blanks were also collected each survey day.

3.4 Wipe Sampling

Wipe sampling was used to quantify lead contamination on work surfaces and personnel. A commercial "wet-wipe" (Wash-a-Bye Baby™ Moist Towelettes) was chosen from three different wipe materials tested (including Wash n' Dri™ Towelettes and Whatman Smeartabs™) based on its low ash content, high recovery, and its low level of background lead, as determined by NIOSH laboratories.[28] Individual wipes were put into lead-free plastic specimen bottles in the laboratory before taking into the field.

Work surfaces considered to be frequently contacted by workers and which were relatively smooth and nonporous (therefore more conducive to efficienct dust removal) were chosen for wipe sampling. These included workbenches, desk and table tops, door knobs, restroom fixtures, and telephones. Additionally, the interiors of company and personal vehicles were wiped (including armrests, dashboards, floor mats, and seats). Cloth fabrics and carpeting were not sampled. If possible, a disposable, cardboard template (pre-cut into various sizes and shapes) was placed on the test surface to permit an accurate and consistent measure of sampled area. Otherwise, a defined surface area was measured by a tape measure. With gloved hands, the wet-wipe was wiped across the test surface in a series of horizontal strokes, then folded over and the area re-wiped in a series of vertical strokes. As much as possible, care was taken to use the same wiping technique and pressure for each sample to reduce variation in collection efficiency; also, the same person collected all the surface wipe samples.

Personal wipe samples were taken from workers' hands and faces. At the end of each workshift, workers were given one wet-wipe from its open sample bottle and instructed to thoroughly wipe both hands (including the palm, back of the hand, and each finger/fingernail) for 30 seconds, removing as much visible contamination as possible. At one shop, workers were then instructed to wash their hands in the restroom, as normally done at the end of each work day, and then to repeat the hand-wiping with another clean wipe to evaluate the effectiveness of their hand washing. All workers were also asked to hold a rectangle cardboard template (with an open area of 25 cm^2) on their forehead while an industrial hygienist wiped the exposed skin with a fresh wet-wipe using a gloved hand (twice in each direction, then once in each direction after folding over the wipe). In order to minimize the sample collection time and maximize cooperation, only one wipe was used for each hands or forehead sample collected.

A minimum of four field blanks per survey day were collected. All wipe samples were stored in their sample bottles before analysis for lead content by AAS following NIOSH Method 7082 (LOD = 3 to 9 μg/wipe; LOQ = 9.3 to 29 μg/wipe); sample results below the LOD were reanalyzed by NIOSH Method 7105 (LOD = .03 to .10 μg/wipe; LOQ = .11 to .34 μg/wipe).[27]

3.5 Particle Sizing

Samples for determining airborne particle-size distributions were collected using 6-stage personal cascade impactors (SKC Series 225™) connected to air sampling pumps (Gillian®) which were worn by radiator mechanics.[29] A flow rate of 2.0 Lpm was used, resulting in cut points, D_p, (particle size with 50% collection efficiency) of 0.5, 0.9, 1.6, 9.8, 14.8, and 21.3 μm. Mylar™ filters and a polyvinyl chloride (PVC) backup filter were used as collection substrates in all impactors; the Mylar™ filters were spray-coated with silicone to minimize particle bounce during sampling. To minimize contamination, all impactors were prepared and unloaded offsite; impactors were taken into the field in new plastic bags each day. Following sampling, the impactors were unloaded, cleaned with acetone and dried before reloading. The lead content of each collection stage was determined by AAS analysis following NIOSH Method 7082 (LOD = 0.9 to 2.0 μg/filter; LOQ = 3.0 to 8.2 μg/filter); sample results below the LOD were reanalyzed by NIOSH Method 7105 (LOD = .02 to .08 μg/filter; LOQ = .07 to .28 μg/filter).

Full-shift impactor samples were collected on all radiator mechanics (personal samples) and at their work stations (area samples) each day. One impactor was taken to the shop each day but not used; the filters in this impactor were used as field blanks.

3.7 Quality Control

All air samples were collected using constant flow pumps calibrated prior to each field survey using a primary calibration standard (i.e., a bubble meter). Flow rates were re-checked at the end of each survey using a bubble meter; if there was significant variation (> 5%) between the pre- and post-survey values, the mid-point of the difference was used to calculate the sample volumes.

All sample analyses were performed by DataChem, Inc., Salt Lake City, Utah, as contracted by NIOSH for analytical services. Field and lab blanks for each sample type (> 5% of the number of field samples, or a minimum of five) were submitted for analysis after each survey. Spiked samples prepared by the NIOSH Measurement Research and Support Branch, Quality Control Coordinator, were also analyzed to ensure analyses were within laboratory quality assurance specifications.

3.8 Miscellaneous Information

Local exhaust ventilation rates were measured using a VelociCalc™ thermo-anemometer (Model 8350, TSI, Inc). A battery-operated psychrometer (Model 566, Belfort Instruments) was used for measuring temperature and humidity. All sampling and survey information was recorded by industrial hygienists using standardized data collection forms (see Appendix F-H).

3.9 Data Analysis

3.9.1 Air and Surface Lead Concentrations

The quantity of lead (in micrograms, μg) measured by AAS analysis was divided by the air volume (in cubic meters, m^3) sampled to determine lead concentrations for each air sample. For wipe samples, the measured lead quantity was divided by the surface area (in m^2) wiped to determine surface concentrations. The areas of all wiped surfaces (except hands) were measured directly or by using a pre-cut sized template; a standard area of 820 cm^2 per pair of hands was used for all workers, as recommended by the Environmental Protection Agency (EPA) when assessing skin exposures.[31]

3.9.2 Time-Weighted Average Concentrations

Time-weighted average exposures over the actual sampling duration ($TWA_{duration}$) were calculated for each worker using either a single full-shift sample or the weighted average of all partial-shift samples as follows:

$$TWA_{duration} = C_a T_a + C_b T_b + \dots C_n T_n \, / \, T_a + T_b + \dots T_n \qquad \textit{(Equation 1)}$$

Where: C_a is the concentration of lead in the first sample worn;
T_a is the sample duration of the first sample worn;
C_b is the concentration of lead in the second sample worn;
T_b is the sample duration of the second sample worn;
C_n is the concentration of lead in the nth sample worn;
T_n is the sample duration of the nth sample worn.

Eight-hour TWA (TWA_8) exposures were calculated to determine compliance with the PEL for airborne lead, as specified by OSHA.[32] If the total sampling duration was greater than or equal to 480 minutes, the TWA_8 was assumed to be the same as the actual-duration TWA. If the total duration sampled was less than 480 minutes, a concentration of zero was assumed (since no further lead exposure was observed) for that remaining duration needed to total 480. The TWA_8 was calculated as follows:

$$TWA_8 = C_aT_a + C_bT_b + \ldots C_nT_n / 480 \qquad \textit{(Equation 2)}$$

Where: C_a is the concentration of lead in the first sample worn;
T_a is the sample duration of the first sample worn;
C_b is the concentration of lead in the second sample worn;
T_b is the sample duration of the second sample worn;
C_n is the concentration of lead in the nth sample worn;
T_n is the sample duration of the nth sample worn.

3.9.3 Particle Size Measurements

The mass median diameter (MMD) and geometric standard deviation (GSD) of lead aerosols at each shop were determined from cascade impactor sample results by graphically plotting the average (of all samples for a given location) cumulative percentage concentration on log probability paper. The MMD is the particle size where 50% of the particle mass is borne by particles larger than the size and 50% of the mass is borne by particles smaller than the size. The GSD is the ratio of the MMD to the Dp_{16}, where Dp_{16} is the particle size for which 16% of the mass is borne by particles smaller than the size.[29]

3.9.4 Statistical Analyses

Point, variance and 95% confidence interval (CI) estimates of mean lead concentrations (including air lead, work surface lead, and personal surface lead) were calculated using the Statgraphics® software package (Version 5, Statistical Graphics Corporation). Any result below the LOD was assigned the LOD/$\sqrt{2}$ value for computing statistics.[33] Descriptive statistics of lead concentrations were calculated by worker as well as by categories such as job, work area, and shop.

4.0 Results

4.1 Participation Rate

Forty radiator shops were identified from the Cincinnati telephone directory. Of the 20 (50%) radiator shops which were sent the initial letter of introduction, nine companies responded, either in writing or by telephone. Three additional companies responded after the second letter was sent. The final response rate was therefore 60% (12 of 20 shops contacted).

Of the 12 respondent shops, nine indicated that lead solder was regularly used for repairing radiators. The other three indicated that radiator repair was no longer their primary business activity. While four shops reported employing more than one full-time radiator mechanic, two of these shops were owned by the same company (one shop was located in Covington, Kentucky and the other in Cincinnati). Therefore, all three contacted shops located in Cincinnati which employed more than one radiator mechanic were selected for sampling. All three owners agreed to participate in the field study.

Every full-time radiator mechanic at each shop was asked to wear air samplers and to allow skin and facial wipe sampling; all (n=8 mechanics) agreed to participate. Additionally, the only mechanic helper employed in any of the shops participated in wipe sampling (he spent greater than 50% of the work shift off-site to make air sampling infeasible). All employee participants were male with between 3 months to 43 years (average = 15 years) of radiator repair experience.

4.2 Description of Survey Sites

4.2.1 Radiator Shop 1

Shop 1 is located in western Cincinnati and has been in operation since 1966. On average, between 8 to 15 radiators are repaired each day; however, during the peak season (summer months), up to 15 radiators are repaired daily. In addition to auto, truck, and industrial radiator repairs, the business performs complete auto service (including wheel alignments, brake and transmission service, and body work), towing, and vehicle storage.

The radiator repair work is performed in a separate section of a large building with multiple drive-in bays, work, and storage areas (refer to diagram in Appendix I). The radiator shop has separate entrances and is completely walled off, except for an access door, from the rest of the building. Each of the shop's four radiator repair stations includes a water-filled test tank, radiator lift, tool stand, and gas torch. Three of the repair stations (#1-#3) are equipped with local exhaust ventilation (LEV) consisting of a canopy-shaped exhaust hood connected to a flexible duct and a ceiling-mounted exhaust blower (Model ER-12, United Air Specialists, Inc). The hood and ducting are connected to a counter-balanced swing arm which permits the mechanic to easily position the capture hood close to the actual work area. An electronic precipitator (SmogBuster™, Eltron Mfg, Inc) designed to clean and recycle air is positioned above two adjacent repair stations (#1 and #2). The shop also has a covered caustic cleaning vat and an enclosed sand blaster with glove boxes (DryBlast™ Model BP-2, Trinity Tool Company).

A shop office for completing paperwork and ordering supplies is located in the radiator shop but some shop business is also performed out of the main office located in a separate building about 50 yards away. The only restroom and a lunchroom are also located in the main office building. Workers eat either offsite or in a separate lunchroom in the main office building; the shop areas are vacated and closed between 12 to 1 pm. According to company management, no eating, drinking or smoking is permitted in the work areas, although these activities were observed there during the survey.

Normally, the radiator shop employs two full-time radiator mechanics (ME and RJ). Another employee (GW), however, works wherever needed in the auto service facility; during the survey, he worked exclusively in the radiator shop. All radiator mechanics are supplied and wear safety glasses, protective gloves (rubber with 12-inch gauntlets and abrasive coating, Edmont Company), and commercially-laundered work pants and shirts which are changed daily at the employee's home. Disposable respirators (Comfort Mask, Model 6985, 3M Company) were available but never observed to be worn when soldering during the survey.

Blood lead testing was conducted, at no charge to the worker, in 1990 for one mechanic (ME) and indicated a BLL of 19 $\mu g/dl$; the other two mechanics (RJ and GW) had BLLs of 23 and 17 $\mu g/dl$, respectively, when tested in 1991. The company has never monitored employee exposures to airborne lead.

4.2.2 Description of Shop 2

Shop 2 is located in central Cincinnati and has been in operation since 1980. Generally, an average of 4-5 radiators are repaired each day, except during the summer when up to 6 radiators are repaired daily. The shop mainly services auto and truck radiators and fuel tanks.

This shop has three radiator repair stations (refer to diagram in Appendix J). Two repair stations (#1 and #2) are adjacent to each other and have a water test tank, radiator lift (tank #1 only), tool stand, and natural gas torch. Each of these two stations is equipped with LEV consisting of a non-flanged hood connected to a flexible duct and exhaust blower (Fumerator® System, Americraft Company). The hood and ducting are connected to a swing arm which permits the mechanic to easily position the hood close to the work area. A wall fan is also positioned between repair stations #1 and #2. The third repair station consists of a ventilated enclosure, resembling a laboratory hood on top of a work table. The enclosure's walls are made of sheet metal and a wall-mounted propeller fan is located at the top of the booth. Access is through a fixed 3-foot by 4-foot opening in the front of the enclosure. This station is used mainly for "tearing down" radiators. This shop also has an enclosed water spray tank connected to waste-water recycling equipment, and an enclosed sand blaster with glove boxes (DryBlast™ Model BP-2, Trinity Tool Company).

A shop office is located in a walled-off area within the same shop building; the office door is normally left closed. The restroom is located about 15 feet across from repair station #1. Workers generally eat lunch in the shop office. "Lead Work Area--No Smoking or Eating" signs are posted at each repair station. No eating or drinking was observed outside of the office during the survey; workers occasionally smoked when away from the immediate repair areas.

Normally, the radiator shop employs two full-time radiator mechanics (DR and RR). A third employee (GR) was hired as a temporary mechanic and mainly performs radiator tear downs. Another worker is employed as a mechanic's helper who generally picks up and delivers radiators from customers. All employee's are supplied with commercially-laundered work pants and shirts which are changed daily at the employee's home. Disposable respirators (Dust and Sanding, Model 8560, 3M Company), and protective goggles (1000 Series, North Company) were available but never observed to be worn when soldering during the survey.

Blood lead testing for the two regular mechanics (DR and RR) indicated BLLs of 35 and 24 µg/dl, respectively, when lasted tested in 1990; testing was provided free of charge to the employees. Air monitoring for lead had never been performed at this shop.

4.2.3 Description of Shop 3

Shop 3 is located in eastern Cincinnati and has been in operation since 1987. On average, 3 radiators are repaired each day (about 5 per day during the summer). In addition to auto and truck radiator repairs, the business services automotive heaters, air conditioners, and exhaust systems.

Radiator repairs are performed in a separate room of a large shop building with multiple drive-in service bays, office, and storage areas (refer to diagram in Appendix K). Entrance to the radiator repair area is either through a door adjacent to the main shop and a door to the storage area. Each of the shop's two radiator repair stations includes a water-filled test tank, radiator lift, tool stand, and propane-air torch. This was the only shop surveyed in which a wire brush was routinely used to clean solder from the heated joints when tearing down radiators. There is no local exhaust ventilation for either repair station. An 18-inch wall fan is located in the wall opposite the repair stations, about 15 feet away. A ceiling-mounted exhaust fan is located about 10 feet above each repair station. The shop also has a covered caustic cleaning vat and an enclosed sand blaster with glove boxes (DryBlast™ Model BP-2, Trinity Tool Company).

A shop office, restrooms, and customer waiting area are located at the opposite end of the shop building. Workers generally eat at a table in the waiting area. No eating, drinking or smoking is permitted in the radiator repair room, although drinking was observed there during the survey.

Normally, the radiator shop employs two full-time radiator mechanics (DP and CC); the owner (LP) also repairs radiators, if necessary. Each worker is supplied with commercially-laundered work pants and shirts which are changed daily at the employee's home. Protective goggles (brand not available) were available but never observed to be worn during the survey; no respirators were available.

Neither air lead sampling or blood lead testing had ever been performed at this shop.

4.3 Radiator Shop Evaluations

All site visits were conducted between July and August, 1991. Four-day surveys were conducted at Shops 1 and 2, while sampling was stopped after only three days at Shop 3 due to lack of repair activity. Owners and employees were each sent written reports of the air and wipe sampling results at their respective shops (see Appendices I through K), which included specific recommendations for improving exposure conditions at their shops. Overall sampling results, including particle size information, are discussed in the following sections.

4.3.1 Air Sampling

A total of 129 air samples were collected and analyzed for airborne lead (PbA); individual sample results (blank-corrected) are presented in Appendix L. The relative frequency distribution of all air lead concentrations (from both personal and area samples) in all the shops is presented in Figure 1. Lead concentrations were generally low; 90% of all air samples collected were below 20 $\mu g/m^3$; the remaining 10% were at or above 94 $\mu g/m^3$.

Air concentrations for all samples collected are summarized by job/area in Table 1. The air concentrations ranged from 0.1 to 810 $\mu g/m^3$; none of the background air samples collected were higher than the sampling LOD.

Fifty-five (43%) of the air samples were collected on radiator mechanics; the overall arithmetic mean (or "average") lead concentration for this group was 52.5 $\mu g/m^3$. Variability within this group was high; the SD was 140 and the coefficient of variation (CV) was 267 percent.

The highest area sampling results were found near the test tank (average of 26.7 $\mu g/m^3$), the area where radiator tear-down and soldering were generally performed. Figure 2 illustrates there were significant differences ($p < .05$) between the average air concentrations found in the radiator repair area of each shop.

Table 2 summarizes air lead concentrations found at Shop 1. The average concentration of 16 samples worn by radiator mechanics was 6.3 $\mu g/m^3$. The highest concentration (18.5 $\mu g/m^3$) at this shop was found for a full-shift sample worn by a mechanic while none of the other 15 personal samples exceeded 10.6 $\mu g/m^3$. Two short-term personal samples collected during continuous soldering (7 minutes at test tank #1 and 30 minutes at tank #2) had concentrations of 7.1 and 4.1 $\mu g/m^3$, respectively (shown in Appendix J).

While the average air lead concentration in the shop office (2.9 $\mu g/m^3$) was well below the PEL, it is actually above the ambient outdoor lead concentration and indicates possible migration between the repair areas and the office. The office door was frequently left open during the workshift.

Results from Shop 2 are shown in Table 3. The average concentration for 26 mechanic samples was 3.0 $\mu g/m^3$. The highest concentration (9.5 $\mu g/m^3$) was found for a partial-shift (165 minute duration) sample worn by a mechanic; none of the other personal samples exceeded 6.0 $\mu g/m^3$. The highest area concentration at this shop was found at the face of the repair booth where radiators were torn down (2.0 $\mu g/m^3$).

The air concentrations found at Shop 3 are presented in Table 4. The 13 samples worn by radiator mechanics averaged 209 $\mu g/m^3$ with a maximum value of 810 $\mu g/m^3$ for a 56-minute personal sample worn while tearing down and resoldering a single radiator. The highest area concentration was 180 $\mu g/m^3$ measured immediately adjacent to the repair station most frequently used during the survey. None of the sample air lead concentrations measured outside of the radiator repair room exceeded 2.0 $\mu g/m^3$ suggesting no migration of airborne lead from the room into the other areas of the building.

Finally, all outdoor ambient air lead concentrations were below the limit of detection indicating that lead concentrations generated inside the shops and released through doors, windows, and exhaust vents did not have any measurable effect during the period of study on the immediate environment. This also indicated that the outdoor ambient air did not contribute to the lead concentrations found inside the shops.

4.3.2 Time-weighted Average Exposures

Time-weighted average (TWA) exposures were calculated over the actual sampling duration ($TWA_{duration}$) and also over an eight-hour duration (TWA_8) for comparison to the OSHA PEL. The TWA each day was calculated for each mechanic resulting in a total of 28 TWA exposures (for both actual and eight-hour durations); results are shown in Appendix M.

The relative frequency distribution of the 28 TWA_8 concentrations is presented in Figure 3. Generally, exposures were very low; 82% of all TWA_8 exposures were below 10 $\mu g/m^3$. Only 7% (2 samples) exceeded the OSHA PEL of 50 $\mu g/m^3$; a total of 11% (3 samples) were greater than the AL (40 $\mu g/m^3$); these high results were at Shop 3.

The TWA_8 exposures for all eight radiator mechanics are summarized in Table 5. The average TWA_8 exposure of all mechanics at each shop ranged from 3.0 $\mu g/m^3$ at Shop 2 to 64.9 $\mu g/m^3$ at Shop 3, a twenty-fold difference. The significant difference ($p < .05$) in exposures between Shop 3 and the other two shops is also shown in Figure 4.

Figure 5 shows the mean TWA_8 exposures for each worker; the two highest means (98.9 and 42.2 $\mu g/m^3$) were for the two mechanics at Shop 3. Figure 6 presents a plot of the individual TWA_8 exposures further illustrating the magnitude of the exposures found at Shop 3. As shown, all three of the TWA_8 exposures which exceeded the OSHA exposure limits were measured at Shop 3; the maximum value was 157 $\mu g/m^3$, which is more than three times the PEL. The highest TWA_8 exposure between the other two shops was only 17 $\mu g/m^3$.

4.3.3 Wipe Sampling

A total of 126 samples were collected to assess surface lead (PbS) contamination; individual sample results (blank-corrected) are presented in Appendix N. The areas of all wiped surfaces (except hands) were measured directly or by using a pre-cut sized template; a standard area of 820 cm^2 per pair of hands was used for all workers, as recommended by the EPA when assessing skin exposures.[31]

The relative frequency distribution of all PbS samples is shown in Figure 7. Twenty-nine percent (36 of 126) of the samples were greater than 10,000 $\mu g/m^2$. When compared to the HUD residential clearance standards, 64% were less than the guideline for window wells (8,640 $\mu g/m^2$) and only 37% were less than the more stringent limit for floors (2,160 $\mu g/m^2$).

A summary of surface lead concentrations in all three radiator shops is shown in Table 6; results from each shop are summarized in Tables 7 through 9. The highest concentration found was 500,000 $\mu g/m^2$ on the edge of a repair test tank. High sample concentrations were also found in personal vehicles (96,000 $\mu g/m^2$), the shop office (84,500 $\mu g/m^2$), and on unwashed hands (78,050 $\mu g/m^2$). Lead was found on every surface wiped, including lunchroom tables and washed hands. Extremely high variability in sample concentrations is indicated by the large SDs (e.g., ranging from 498 to over 169,000 for data in Table 6).

The average PbS concentration by area is shown in Figure 8. Large differences in the surface area wiped and in the sample frequency for each location make comparisons of averages by location tenuous.

Table 10 summarizes PbS concentrations found on individual workers' hands, foreheads, shoes, and personal vehicles. The average lead concentrations ranged from 5,453 to 51,220 $\mu g/m^2$ on unwashed hands, 122 to 5,000 $\mu g/m^2$ on foreheads, 20,000 to 46,000 $\mu g/m^2$ on shoes, and 976 to 44,000 $\mu g/m^2$ in vehicles. Figure 9 further illustrates the average PbS concentrations on the unwashed hands of shop workers.

As described above, hand wipe samples were collected both before and after washing at Shop 2. The average concentrations ranged from 259 to 974 $\mu g/m^2$ on washed hands (Table 10). The averages for "before" and "after" washing for each worker at Shop 2 are plotted in Figure 10; in most cases, there was a significant difference ($p < .05$) in means for unwashed and washed hands. Interestingly, an average of more than 970 $\mu g/m^2$ was found on one worker's washed hands (maximum value of over 2,400 $\mu g/m^2$). Figure 11 shows the significant difference ($p < .05$) between the means of all unwashed and washed hand samples.

4.3.4 Particle Sizing

Figures 12 through 14 show the aerosol size distributions, by shop, for the different sampling locations (radiator mechanic and repair tank); Figure 15 shows the mean distributions at the two different locations for all shops. In general, the distributions were similar for both intra-and inter-shop comparisons. An exception was the much smaller particle size measured from area samples near the repair tanks at Shop 1. Most of the distributions, however, indicate a large portion of the lead mass can be found in particle sizes larger than 10 μm. This is illustrated by data shown in Table 11 which presents the mass median diameters (MMD) of lead aerosols from the samples collected on radiator mechanics and at the repair stations. All the MMDs determined from personal samples were equal to or greater than 10 μm. The GSDs varied from 4 to 7 indicating a rather flat distribution over the entire size range.

4.3.5 Ventilation Measurements

The results of ventilation measurements at each radiator shop are summarized in Table 12. The velocities at the face of the hoods were all above 100 feet per minute (fpm), which is the minimum capture velocity recommended by the ACGIH for contaminants of low to moderate toxicity (eg. non-carcinogens) released at low velocity into moderately still air.[34]

The surveys at these shops were all conducted during warm to hot weather (July to August) which generally led to most windows and doors being left open. Though not measured, natural air breezes were observed using smoke tubes throughout the work areas. While disturbing room air currents tend to interfere with the effectiveness of LEV capture, they also help dilute contaminant concentrations. The conditions during these surveys may not be representative of those found during winter months when shops are normally "closed-up" to protect against colder temperatures.

5.0 Discussion

All three surveys of radiator shops described in this report were conducted in summer months during hot weather when radiator repair activity was near peak levels compared to the rest of the year, according to shop personnel. While natural ventilation through the shops may have been greater than during winter months when doors and windows are left closed, the effects of disturbing air currents are largely unpredictable. Therefore, while the results reported herein may be considered to represent worst case exposures, this should be confirmed by winter surveys, when repair volume is generally about one-quarter of that seen during the summer.

Of the three shops surveyed, only Shop 3 could be described as "small, dirty, and poorly ventilated", a description previously used to characterize many radiator shops in other studies.[1,2] The other two shops were spacious, clean, and orderly, with effective and well-maintained ventilation systems. Interestingly, Shop 3 was the newest of the three shops, being built only four years ago.

Two primary factors are probably responsible for the major differences in lead concentrations between Shop 3 and the other shops surveyed. First, only the radiator mechanics at Shop 3 used a wire brush to clean solder from the soldered joints when tearing down radiators. This not only generated a large amount of lead dusts, but shortened the distance between the worker's breathing zone (where the sampler was worn) and the radiator as he leaned over while brushing. This may also explain the larger mean particle sizes seen at Shop 3, suggesting that there may be more exposure to large-sized lead dusts at Shop 3 than to primarily smaller-sized lead fumes as seen at Shops 1 and 2. This suggests that wire brushing of soldered parts may be a potential source of lead exposure and demonstrates that such a work practice should be avoided.

Second, the lack of effective engineering controls in Shop 3 contributed to excessive airborne lead exposures. The use of a single wall-mounted and two roof-mounted propeller fans was ineffective in reducing lead exposures below the OSHA PEL. On the other hand, local exhaust ventilation at the other two shops where face velocities of at least 100 fpm were maintained was found to effectively control airborne lead exposures to well below the PEL. The adjustable-arm, flexible duct hoods in these shops are large enough that the mechanic did not have to constantly reposition the hood as he works on a radiator, and yet are easily movable when necessary. This ergonomic consideration is important in predicting how frequently the worker will use the exhaust hood and therefore how effectively exposures are controlled.

Because of the lack of engineering controls and the magnitude of airborne exposures, appropriate NIOSH-approved respirators should be worn by all mechanics at Shop 3 whenever tearing down or soldering radiators (see Appendix O for NIOSH recommended respirators). However, respirators are not to be used instead of engineering controls but rather only in the interim until a suitable LEV system can be installed. In fact, respirators should rarely be required in radiator shops, based on recent research by the NIOSH Division of Physical Sciences and Engineering which has resulted in affordable (less than $1000) and effective ventilation control systems available to all radiator shops, including those which may lack resources for purchasing expensive, elaborate engineering controls.[3]

The highest surface lead concentrations in the three radiator shops were generally found in the immediate area where radiators were being torn down and resoldered. This finding might have been predictable since these activities are the primary sources of lead contamination at the radiator shops. Less expected was the lead contamination shown to be pervasive throughout rest of the shop areas, especially at the high levels found in the shop office. Furthermore, lead was not confined to the workplace as indicated by the high levels measured in the personal vehicles of shop mechanics. These later findings are particularly disturbing since lead was found in areas where workers frequently eat and smoke and because it indicates that lead is being carried away from the workplace. Therefore, workers, customers, and families are potentially being exposed to lead through skin contact, and possibly resulting in the ingestion of lead.

Skin wipes indicated that mechanics' hands and foreheads become highly contaminated with lead during repair activities. Work gloves were supplied in only one radiator shop (Shop 1), mainly for protection from heat, but their use was observed to be irregular. Also, one of the highest surface lead concentrations found during the survey was on a wipe sample taken from the inside of a used glove (29,200 $\mu g/m^2$). These same gloves were used for the entire survey duration without replacement despite being visibly contaminated.

While hand washing significantly reduced lead contamination, high levels (i.e., compared with the HUD clearance criteria) were still measured after washing in the one shop in which before and after samples were collected (Shop 2). Although the washing procedure used in this shop (using a liquid detergent and hot running water) is appropriate for removing lead, cleaning habits are highly subjective and personal, therefore quite difficult to assess and to control. Effective cleaning undoubtedly varies greatly from one worker to the next and from one washing to the next. Another explanation for the lead contamination found after washing hands is the potential for recontaminating clean hands, which is suggested by some of the data from this shop. For instance, high lead levels were found on the restroom lightswitch (18,180 $\mu g/m^2$) and the toilet flusher (5263 μg/m^2). Also, this shop used a cloth towel roll-type dispenser rather than a paper towel single-sheet dispenser, which required the worker to push a button and pull down a used section of towel before reaching a clean section. While the amount of lead transferred to washed hands by this procedure is probably minimal (no samples were taken on the machine), it does present the potential for cross contamination and its continued use should be reconsidered.

The extremely high SDs and CVs for the wipe sampling results illustrate the high variability in measured surface lead concentrations. While much of the observed variability is due to actual differences in lead contamination on different surfaces, some of this variability is probably due to the differences in collection efficiency for each sample (due largely to inconsistent hand sizes and wiping techniques between participants and between samples). Others have noted also that a single wipe sample is not acceptably efficient or precise, and at least three wipes may be necessary to achieve high recoveries of surface lead dusts.[24] While wipe sampling may therefore be considered only semi-quantitative, these survey results do indicate the presence and relative magnitude of lead on several surfaces likely to be contacted by workers.

The size distributions of sampled lead aerosols were generally similar throughout the locations and shops surveyed. The distributions indicate a large portion of the lead mass can be found in particle sizes greater than 10 μm. The narrow range of GSDs for the aerosol distributions in radiator shops are similar to those found by Hodgkins in lead battery plants but quite different than was found by Froines in a brass foundry.[20,21] Like the Hodgkins study, most samples collected in this study were personal samples, which may have contributed to the similarity in results; the small GSDs indicate that the sampled workers are exposed to aerosols of similar size distributions. Froines, however, collected area samples and reported large GSDs (up to 15.7) for some of the areas sampled indicating distinctly different size distributions from various work processes, possibly due to differences in the physical nature of lead particles present (e.g. smaller sized fumes versus larger sized dusts).

These results suggest that the knowledge of the size distributions of lead aerosols found in lead industries, such as radiator shops, may be important in predicting PbB levels. For instance, while air lead levels may be well below the PEL, determination of particle sizes may indicate a relatively large amount of lead in particle sizes less than, say, 10 μm, and therefore more likely to be respirable. This situation may be more significant if workers are exposed to high concentrations of larger sized (eg. >10 μm) particles which are not as likely to be deposited in the alveolar region of the lung and readily absorbed into the blood. This may require different types of work practices and ventilation control strategies for effectively controlling worker BLLs, depending on the particle size of the lead aerosol exposure.

This project helps to emphasize several important public health issues. First, radiator repair should be recognized as associated with increased risk of lead poisoning. Recognizing and controlling sources of lead exposure are important, considering the toxicity of lead.

Second, this project illustrates the dilemma of small businesses concerning health and safety conditions. Frequently, owners may be poorly informed about hazardous conditions in their shops and the applicable health and safety regulations for controlling workplace exposures. Even if they are aware of conditions and requirements, they may lack the information and financial resources to implement the regulations or correct problems.

Third, ingested lead has received minor attention, compared to inhaled lead, as a major route of entry for lead poisoning. However, the results from this survey indicate that hand, facial, and work surface lead contamination may be significant sources which potentially contribute to ingested lead by radiator mechanics. Further, radiator repair work also presents a potential risk of lead poisoning to the families of mechanics, as illustrated by the high levels of lead carried home on their skin, shoes, and automobiles.

Many previous studies have also indicated that lead may be carried home by workers in lead-industries, resulting in potential exposure and lead poisoning of family members.[36-41] This is a particular problem where young children are involved since national data indicate that children ages 6 months through 2 years are at highest risk of lead poisoning.[16] Toddlers are especially liable to ingest lead in contaminated environments because of normal mouthing behavior and increased hand contact with dirt and dust.[42] Children in this age group are also more susceptible than older persons to lead-related neurobehavioral toxicity.[43-44] Growing evidence indicates that BLLs in the range of 10 to 15 μg/dL and above affect cognitive development and behavior in young children.[43-46] Finally, prenatal exposure to lead is associated with reduced gestational age, birthweight, and early mental development at prenatal maternal BLLS as low as 10 to 15 μg/dL.[47]

Since inhaled lead has been primarily emphasized and considered the major route of entry by occupational health authorities, most requirements for personal hygiene facilities, clothing changes, and housekeeping are predicated on airborne lead levels with relatively minor consideration of surface lead contamination. For example, OSHA recognizes wipe sampling results to be useful for identifying lead-contaminated areas but has not yet established specific criteria for surface dust levels which can be used for determining the need for any corrective action. The results from this survey emphasize the need for routine wipe sampling, pertinent comparison criteria and, where necessary, for implementation and strict adherence to policies directed to personal and environmental hygiene to minimize the potential of lead ingestion. Cleaning of frequently contacted surfaces, especially desktops, telephones, restrooms, and lunch tables using a high efficiency particulate (HEPA) filter vacuum and detergent solutions should be performed daily. Shop rules which prohibit eating, drinking or smoking in any areas which are not physically separated from the work areas, cleaned daily, and in which unwashed workers are not allowed to enter should be implemented and strictly enforced. This would effectively eliminate any eating or smoking in most shop offices.

Workers should be frequently reminded (eg., by posting signs) to thoroughly clean their hands and face before any eating, drinking, or smoking. Workers should be required to wear commercially-laundered work uniforms provided daily by the employer and prohibited from taking dirty uniforms and workshoes from the workplace. (The commercial laundry firm must be advised, in writing, of the lead contamination and of its potentially harmful effects).

Conscientious personal hygiene practices must be emphasized whenever working with or around lead. Showering should be required of all employees before leaving radiator shops to further minimize possible contamination of cars and homes and prevent secondary lead exposures to workers' families. Finally, all shop employees (and their family members, if feasible) should be educated regarding the hazards of lead, including the potential for take-home contamination and the higher susceptibility to lead poisoning in young children.

6.0 Summary

Area and personal sampling for airborne and surface lead was conducted in three Cincinnati radiator repair shops. A total of 129 air samples and 126 wipe samples were collected. The highest air concentrations were found near the repair stations where mechanics work with molten lead-based solder. The mean eight-hour TWA lead exposure for mechanics was 15.2 $\mu g/m^3$ (SD=33.3) with a range of 0.9 to 157 $\mu g/m^3$. The two shops which used local exhaust ventilation systems were found to have effectively controlled worker exposures to airborne lead. Personal time-weighted exposures averaged less than one-fifth the OSHA PEL (50 $\mu g/m^3$) in these shops. However, exposures in the third shop, in which there was no local ventilation, were frequently above the PEL.

These survey results also indicate that sources of exposure other than airborne lead, such hand, facial, and work surface contamination, may make a significant contribution to the total lead exposure. Lead contamination on work surfaces in these shops was found as high as 500,000 $\mu g/m^2$. Lead dust was also found in lunch areas, on hands of workers (both before and after washing), on street shoes, and in personal vehicles. As with airborne lead, the individual hand, facial, and surface lead levels varied widely throughout the surveys.

These results are similar to those found in other studies of radiator repair shops and confirm the potential for excessive lead exposures of radiator mechanics as well as their families. Lead poisoning is entirely preventable--if actions are taken to eliminate exposures to lead. These should include: the installation of an effective local exhaust ventilation system; the mandatory use of protective equipment, such as respirators (until exposures are below the PEL), and gloves and uniforms which are replaced daily; a strict adherence to personal and environmental hygiene; an enforced prohibition of eating and smoking in all lead-contaminated areas; the implemention of routine environmental and medical monitoring programs; and training to increase the awareness of the problems associated with lead use. Radiator shop owners should recognize and meet their inherent obligation to protect not only their employees from lead poisoning but also the employees' families.

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TABLE 1

SUMMARY OF AIR LEAD CONCENTRATIONS (μG/M^3) AT RADIATOR REPAIR SHOPS #1-3

JOB/AREA	N	GM	GSD	AVG	SD	SE	CV	MIN	MAX	95% CI	
Radiator mechanic	55	6.2	6.4	52.5	140.0	18.9	267	0.3	810.0	15.5	89.5
Radiator repair: general area	17	1.4	4.8	7.7	22.9	5.7	298	0.1	95.6	(0)	19.0
: test tank	17	2.9	7.7	26.7	56.9	13.8	213	0.1	180.0	(0)	53.8
: repair booth	3	1.1	2.1	1.3	0.8	0.4	58	0.5	2.0	0.4	2.2
: office	7	1.5	1.9	1.9	1.7	0.6	90	0.9	5.7	0.6	3.1
Main office	6	0.4	2.8	0.5	0.4	0.2	77	0.1	1.0	0.2	0.8
Lunch area	10	0.5	2.8	0.7	0.5	0.2	67	0.1	1.5	0.4	1.0
Outside: lev exhaust	4	0.1	1.4	0.2	0.1	0.0	40	0.1	0.2	0.1	0.2
Background	10	0.1	0.0	0.1	0.0	0.0	0	0.1	0.1	0.1	0.1
TOTAL	129	1.9	7.9	27.2	96.4	8.5	355	0.1	810.0	10.5	43.8

N - number of samples
GM - geometric mean
GSD - geometric standard deviation
AVG - arithmetic mean
SD - standard deviation
SE - standard error
CV - coefficient of variation
MIN - minimum value
MAX - maximum value
95%CI - 95 percent confidence interval (lower and upper values) on the AVG
(0) - calculated lower CI value is less than zero

TABLE 2

SUMMARY OF AIR LEAD CONCENTRATIONS ($\mu G/M^3$) AT RADIATOR REPAIR SHOP #1

JOB/AREA	N	GM	GSD	AVG	SD	SE	CV	MIN	MAX	95% CI	
Radiator mechanic: ME	6	5.1	2.1	6.7	6.1	2.5	91	2.2	18.5	1.8	11.5
:RJ	5	5.6	1.3	5.7	1.7	0.7	29	4.1	8.1	4.3	7.2
:GW	5	5.7	1.6	6.3	3.0	1.3	48	3.3	10.6	3.7	8.9
Subtotal	16	5.4	1.7	6.3	3.9	1.0	63	2.2	18.5	4.3	8.2
Radiator repair: general area	7	1.3	2.0	1.6	1.3	0.5	85	0.5	4.5	0.6	2.6
: test tank	7	2.3	1.5	2.5	1.0	0.4	42	1.5	4.4	1.7	3.2
: office	3	2.3	2.2	2.9	2.5	1.4	86	1.3	5.7	0.1	5.7
Main office	3	0.1	1.9	0.2	0.1	0.1	70	0.1	0.3	0.0	0.3
Lunch area	3	0.1	1.5	0.1	0.1	0.0	43	0.1	0.2	0.1	0.2
Background	3	0.1	0.0	0.1	0.0	0.0	0	0.1	0.1	0.1	0.1
TOTAL	42	1.5	4.6	3.3	3.6	0.6	108	0.1	18.5	2.2	4.4

N = number of samples
GM = geometric mean
GSD = geometric standard deviation
AVG = arithmetic mean
SD = standard deviation
SE = standard error
CV = coefficient of variation
MIN = minimum value
MAX = maximum value
95%CI = 95 percent confidence interval (lower and upper values) on the AVG

TABLE 3

SUMMARY OF AIR LEAD CONCENTRATIONS ($\mu G/M^3$) AT RADIATOR REPAIR SHOP #2

JOB/AREA	N	GM	GSD	AVG	SD	SE	CV	MIN	MAX	95% CI	
Radiator mechanic: DR	18	2.0	2.3	2.5	1.7	0.4	65	0.3	6.0	1.8	3.3
: GR	4	5.9	1.6	6.4	2.7	1.4	42	3.0	9.5	3.7	9.0
: RR	4	1.6	1.4	1.6	0.5	0.2	29	1.0	2.1	1.2	2.1
Subtotal	26	2.2	2.3	3.0	2.2	0.4	75	0.3	9.5	2.1	3.9
Radiator repair: general area	4	0.3	2.3	0.4	0.3	0.1	65	0.1	0.7	0.2	0.7
: test tank	7	0.7	2.5	0.9	0.5	0.2	53	0.1	1.3	0.5	1.2
: repair booth	3	1.1	2.0	1.3	0.8	0.4	58	0.5	2.0	0.4	2.2
: office/lunch	4	1.1	1.2	1.2	0.3	0.1	22	0.9	1.5	0.9	1.4
Outside: lev discharge	4	0.1	1.4	1.2	0.1	0.0	40	0.1	0.2	0.1	0.2
Background	4	0.1	0.0	0.1	0.0	0.0	0	0.1	0.1	0.1	0.1
TOTAL	56	1.0	3.6	1.8	1.9	0.0	109	0.1	9.5	1.7	1.8

N = number of samples
GM = geometric mean
GSD = geometric standard deviation
AVG = arithmetic mean
SD = standard deviation
SE = standard error
CV = coefficient of variation
MIN = minimum value
MAX = maximum value
95%CI = 95 percent confidence interval (lower and upper values) on the AVG

TABLE 4

SUMMARY OF AIR LEAD CONCENTRATIONS ($\mu G/M^3$) AT RADIATOR REPAIR SHOP #3

JOB/AREA	N	GM	GSD	AVG	SD	SE	CV	MIN	MAX	95% CI	
Radiator mechanic: DP	6	97.8	8.7	288.2	302.3	123.4	105	3.4	810.0	46.3	530.1
: CC	7	34.0	16.1	140.4	139.1	52.6	99	0.4	352.0	37.4	243.4
Subtotal	13	55.3	11.9	208.6	231.6	64.2	111	0.4	810.0	82.7	334.5
Radiator repair: general area	6	3.9	7.2	19.8	37.7	15.4	191	0.6	95.6	(0)	49.9
: test tank	3	141.4	1.2	143.7	32.1	18.6	22	119.0	180.0	107.3	180.0
Main office	3	0.8	1.2	0.8	0.2	0.1	18	0.7	1.0	0.7	1.0
Lunch area	3	0.7	1.3	0.7	0.2	0.1	25	0.6	0.9	0.5	0.9
Background	3	0.1	0.0	0.1	0.0	0.0	0	0.1	0.1	0.1	0.1
TOTAL	31	8.6	19.1	105.4	176.9	31.8	168	0.1	810.0	43.1	167.6

N = number of samples
GM = geometric mean
GSD = geometric standard deviation
AVG = arithmetic mean
SD = standard deviation
SE = standard error
CV = coefficient of variation
MIN = minimum value
MAX = maximum value
95%CI = 95 percent confidence interval (lower and upper values) on the AVG
(0) = calculated lower CI value is less than zero

TABLE 5

SUMMARY OF PERSONAL TIME-WEIGHTED AVERAGE$_{(8\text{-hour})}$ LEAD EXPOSURES ($\mu G/M^3$) OF RADIATOR REPAIR MECHANICS AT SHOPS #1-3

SHOP	MECHANIC	N	GM	GSD	AVG	SD	SE	CV	MIN	MAX	95% CI	
1	ME	4	4.9	2.3	6.8	6.9	3.4	102	2.6	17.0	0.0	13.5
	RJ	4	5.1	1.3	5.2	1.4	0.7	28	4.3	7.3	3.8	6.6
	GW	4	4.6	1.8	5.1	2.4	1.2	47	2.1	7.2	2.7	7.5
	Shop total	12	4.9	1.7	5.7	4.0	1.1	70	2.1	17.0	3.5	7.9
2	DR	4	2.3	1.5	2.4	0.8	0.4	35	1.3	3.2	1.6	3.2
	GR	3	5.6	1.1	5.6	0.4	0.3	8	5.1	5.9	5.1	6.1
	RR	4	1.5	1.5	1.6	0.5	0.3	34	0.9	2.1	1.0	2.1
	Shop total	11	2.5	1.9	3.0	1.8	0.6	62	0.9	5.9	1.9	4.0
3	DP	2	80.0	2.6	98.9	82.2	58.1	83	40.8	157.0	(0)	212.8
	CC	3	27.5	3.2	42.2	44.5	25.7	105	9.0	92.7	(0)	92.5
	Shop total	5	42.2	3.1	64.9	60.3	27.0	93	9.0	157.0	12.0	117.8
	TOTAL	28	5.5	3.3	15.2	33.3	6.3	219	0.9	157.0	2.9	27.5

OSHA PERMISSIBLE EXPOSURE LIMIT = 50
OSHA ACTION LEVEL = 30

N = number of samples
GM - geometric mean
GSD - geometric standard deviation
AVG - arithmetic mean
SD - standard deviation
SE - standard error
CV - coefficient of variation
MIN - minimum value
MAX - maximum value
95%CI - 95 percent confidence interval (lower and upper values) on the AVG
(0) - calculated lower CI value is less than zero

TABLE 6

SUMMARY OF SURFACE LEAD CONCENTRATIONS (μG/M²) AT RADIATOR REPAIR SHOPS #1-3

JOB/AREA	N	GM	GSD	AVG	SD	SE	CV	MIN	MAX	95% CI	
AREA SAMPLES											
Radiator repair area	10	29,001	4.6	96,791	169,929	53,736	176	5,300	500,000	(0)	210,645
Shop office	6	3,542	7.4	17,594	33,222	13,563	189	410	84,500	(0)	44,177
Restroom	4	5,649	4.1	9,386	7,816	3,909	84	800	18,180	1,724	17,048
Lunchroom	2	277	4.5	448	498	352	111	96	800	(0)	8,110
Personal vehicle	12	8,679	5.8	25,745	32,750	9,454	127	700	96,000	7,215	44,275
Shop vehicle	2	5,357	6.7	10,950	13,506	9,550	123	1,400	20500	(0)	29,668
PERSONAL SAMPLES											
Radiator mechanic: hands[a] (unwashed)	50	7,461	2.6	11,695	13,832	1,956	118	646	78,050	7,861	15,529
: forehead	20	370	5.2	1,162	1,741	389	150	49	6,000	400	1,924
: street shoes	2	30,332	1.8	3,300	18,385	13,000	56	20,000	46,000	7,520	58,480

HUD CLEARANCE CRITERIA (residential housing): floors: 2,160
window sills: 5,400
window wells: 8,640

[a]Area = 820 cm² based on EPA criteria[31]
N = number of samples
GM = geometric mean
GSD = geometric standard deviation
AVG = arithmetic mean
SD = standard deviation
SE = standard error
CV = coefficient of variation
MIN = minimum value
MAX = maximum value
95%CI = 95 percent confidence interval (lower and upper values) on the AVG
(0) = calculated lower CI value is less than zero

TABLE 7

SUMMARY OF SURFACE LEAD CONCENTRATIONS ($\mu G/M^2$) AT RADIATOR REPAIR SHOP #1

JOB/AREA	N	GM	GSD	AVG	SD	SE	CV	MIN	MAX	95% CI	
AREA SAMPLES											
Radiator repair area	7	34,497	5.8	127,271	198,833	75,152	156	5,300	500,000	(0)	274,569
Shop office	3	11,004	9.0	33,448	44,740	25,831	134	1,067	84,500	(0)	84,007
Restroom	1	13,300	0.0	13,300	0	-	-	-	-	-	-
Lunchroom	1	96	0.0	96	0	-	-	-	-	-	-
Personal vehicle	3	1,573	1.8	1,761	1,125	649	63	976	3,066	509	3,053
PERSONAL SAMPLES											
Radiator mechanic: hands[a] (unwashed)	21	11,011	1.8	13,209	9,601	2,095	73	4,950	41,415	9,103	17,315
: forehead	12	118	2.4	171	160	46	94	49	488	81	281
HUD CLEARANCE CRITERIA (residential housing): floors: 2,160 window sills: 5,400 window wells: 8,640											

[a]Area = 820 cm^2 based on EPA criteria[31]
N = number of samples
GM = geometric mean
GSD = geometric standard deviation
AVG = arithmetic mean
SD = standard deviation
SE = standard error
CV = coefficient of variation
MIN = minimum value
MAX = maximum value
95%CI = 95 percent confidence interval (lower and upper values) on the AVG
(0) = calculated lower CI value is less than zero

TABLE 8

SUMMARY OF SURFACE LEAD CONCENTRATIONS ($\mu G/M^2$) AT RADIATOR REPAIR SHOP #2

JOB/AREA	N	GM	GSD	AVG	SD	SE	CV	MIN	MAX	95% CI	
AREA SAMPLES											
Radiator repair area	1	18,750	0.0	18,750	-	-	-	-	-	-	-
Shop office/lunch area	2	1,261	4.9	2,143	2,450	1,733	114	40	3,875	(0)	5,540
Restroom	2	9,782	2.4	11,722	9,134	6,459	78	5,263	18,180	(0)	24,382
Personal vehicle	9	15,337	5.2	33,733	34,457	11,486	102	700	96,000	11,220	56,246
Shop vehicle	2	5,357	6.7	10,950	13,506	9,550	123	1,400	20500	(0)	29,668
PERSONAL SAMPLES											
Rad mechanic:hands[a] (unwashed)	26	4,906	2.3	6,788	5,6192	1,102	83	646	21,950	4,628	8,948
: hands[a] (washed)	18	409	2.4	593	589	139	99	122	2,439	321	865
: forehead	8	2,042	2.2	2,650	1,994	705	75	800	6,000	1,268	4,032
: street shoes	2	30,332	1.8	3,300	18,385	13,000	56	20,000	46,000	7,520	58,480

HUD CLEARANCE CRITERIA (residential housing): floors: 2,160
window sills: 5,400
window wells: 8,640

[a]Area = 820 cm^2 based on EPA criteria[31]
N = number of samples
GM = geometric mean
GSD = geometric standard deviation
AVG = arithmetic mean
SD = standard deviation
SE = standard error
CV = coefficient of variation
MIN = minimum value
MAX = maximum value
95%CI = 95 percent confidence interval (lower and upper values) on the AVG
(0) = calculated lower CI value is less than zero

TABLE 9

SUMMARY OF SURFACE LEAD CONCENTRATIONS ($\mu G/M^2$) AT RADIATOR REPAIR SHOP #3

JOB/AREA	N	GM	GSD	AVG	SD	SE	CV	MIN	MAX	95% CI	
AREA SAMPLES											
Radiator repair area	2	19,649	3.8	29,129	30,411	21,504	104	7,625	50,633	(0)	71,277
Shop office	1	933	0.0	933	0	-	-	-	-	-	-
Restroom	1	800	0.0	800	0	-	-	-	-	-	-
Lunchroom	1	800	0.0	800	0	-	-	-	-	-	-
PERSONAL SAMPLES											
Radiator mechanic: hands* (unwashed)	3	18,497	8.5	43,618	38,796	22,399	89	1,583	78,050	-284	87,520
HUD CLEARANCE CRITERIA (residential housing): floors: 2,160; window sills: 5,400; window wells: 8,640											

*Area = 820 cm² based on EPA criteria[31]
N = number of samples
GM = geometric mean
GSD = geometric standard deviation
AVG = arithmetic mean
SD = standard deviation
SE = standard error
CV = coefficient of variation
MIN = minimum value
MAX = maximum value
95%CI = 95 percent confidence interval (lower and upper values) on the AVG
(0) = calculated lower CI value is less than zero

TABLE 10

SUMMARY OF SURFACE LEAD CONCENTRATIONS (μG/M²)
ASSOCIATED WITH RADIATOR MECHANICS AT RADIATOR REPAIR SHOPS #1-3

SHOP	WORKER	SURFACE SAMPLED	N	GM	GSD	AVG	SD	SE	CV	MIN	MAX	95% CI	
1	ME	hands (unwashed)	7	7,159	1.3	7,355	1,850	699	254	5,317	9,463	5,985	8,725
		forehead	4	151	2.7	216	200	100	92	60	488	20	412
		vehicle	1	3,066	0.0	3,066	0	-	-	-	-	-	-
		glove (inside)	1	29,200	0.0	29,200	0	-	-	-	-	-	-
	RJ	hands (unwashed)	7	19,191	1.8	22,007	12,308	4,652	56	9,220	41,415	12,889	31,125
		forehead	4	101	2.1	122	79	39	65	49	207	46	198
		vehicle	1	1,300	0.0	1,300	0	-	-	-	-	-	-
	GW	hands (unwashed)	7	9,716	1.5	10,264	3,460	1,308	34	4,950	14,585	7,700	12,828
		forehead	4	109	2.9	174	204	102	117	49	475	(0)	374
		vehicle	1	976	0.0	976	0	-	-	-	-	-	-
2	DR	hands (unwashed)	7	4,823	1.7	5,453	2,823	1,067	52	2,440	9,512	3,362	7,544
		hands (washed)	5	635	2.0	756	476	213	63	280	1,341	339	1,174
		forehead	3	2,308	1.9	2,667	1,847	1,066	69	1,600	4,800	578	4,756
		vehicle	4	36,855	2.0	44,000	27,725	13,862	63	19,000	68,000	16,830	71,170
		streetshoes	1	20,000	0.0	20,000	0	-	-	-	-	-	-
	GR	hands (unwashed)	5	5,204	2.5	7,293	6,317	2,825	87	2,075	15,853	1,756	12,830
		hands (washed)	4	590	3.3	974	1,039	519	107	159	2,439	-43	1,991
		forehead	2	4,899	1.3	5,000	1,414	1,000	28	4,000	6,000	3,040	6,960

TABLE 10
(continued)

SUMMARY OF SURFACE LEAD CONCENTRATIONS ($\mu G/M^2$)
ASSOCIATED WITH RADIATOR MECHANICS AT RADIATOR REPAIR SHOPS #1-3

SHOP	WORKER	SURFACE SAMPLED	N	GM	GSD	AVG	SD	SE	CV	MIN	MAX	95% CI	
	RR	hands (unwashed)	7	3,932	3.0	5,998	5,004	1,891	83	646	13,415	2,292	9,704
		hands (washed)	5	234	1.7	259	122	54	47	122	414	153	365
		forehead	3	1,008	1.5	1,067	462	267	43	800	1,600	544	1,590
		vehicle	5	7,606	6.8	25,520	40,104	17,935	157	700	96,000	-9633	60,673
		streetshoes	1	46,000	0.0	46,000	0	-	-	-	-	-	-
	SC*	hands (unwashed)	7	5,969	2.4	8,553	8,080	3,054	95	2,195	21,950	2,567	14,538
		hands (washed)	4	327	2.4	429	320	160	75	135	730	115	743
3	DP	hands (unwashed)	2	11,115	15.7	39,817	54,070	38,234	136	1,583	78,050	(0)	114,755
	CC	hands (unwashed)	1	51,220	0.0	51,220	0	-	-	-	-	-	-
HUD CLEARANCE CRITERIA (residential housing): floors: 2,160 window sills: 5,400 window wells: 8,640													

* radiator mechanic helper
N = number of samples
GM = geometric mean
GSD = geometric standard deviation
AVG = arithmetic mean
SD = standard deviation
SE = standard error
CV = coefficient of variation
MIN = minimum value
MAX = maximum value
95%CI = 95 percent confidence interval (lower and upper values) on the AVG
(0) = calculated lower CI value is less than zero

TABLE 11

PARTICLE SIZE OF LEAD AEROSOLS AT RADIATOR REPAIR SHOPS #1-3

SHOP	LOCATION	N	MMD (μm)	GSD
1	Radiator Mechanic	6	10	5
	Repair Area	7	1	6
2	Radiator Mechanic	10	10	7
	Repair Area	4	6	7
3	Repair Mechanic	3	15	4
	Repair Area	1	11	4

N = number of samples
MMD = mass median diameter
μm = micrometers
GSD = geometric standard deviation

TABLE 12

SUMMARY OF LOCAL EXHAUST VENTILATION (LEV) DATA AT RADIATOR REPAIR SHOPS #1-3

SHOP	REPAIR STATION	HOOD SHAPE	OPENING SIZE	N	AVG FACE VELOCITY (fpm)	AVG HOOD AIRFLOW (cfm)	AVG CAPTURE VELOCITY (fpm)		
							6"	12"	24"
1	1	tapered canopy	20" X 24"	3	111	370	68	38	32
	2	tapered canopy	20" X 24"	3	101	337	53	36	23
	3	tapered canopy	20" X 24"	2	348	1157	198	89	29
2	1	plain circular	14.24"	3	703	773	278	99	35
	2	plain circular	14.25"	3	752	827	243	98	28
	3	enclosing hood	48" X 37"	3	119	1460	na	na	na
3	(no local exhaust ventilation used)								

N = number of samples
AVG = arithmetic mean
fpm = feet per minute
cfm = cubic feet per minute

Figure 1
Frequency Histogram: PbA Concentrations

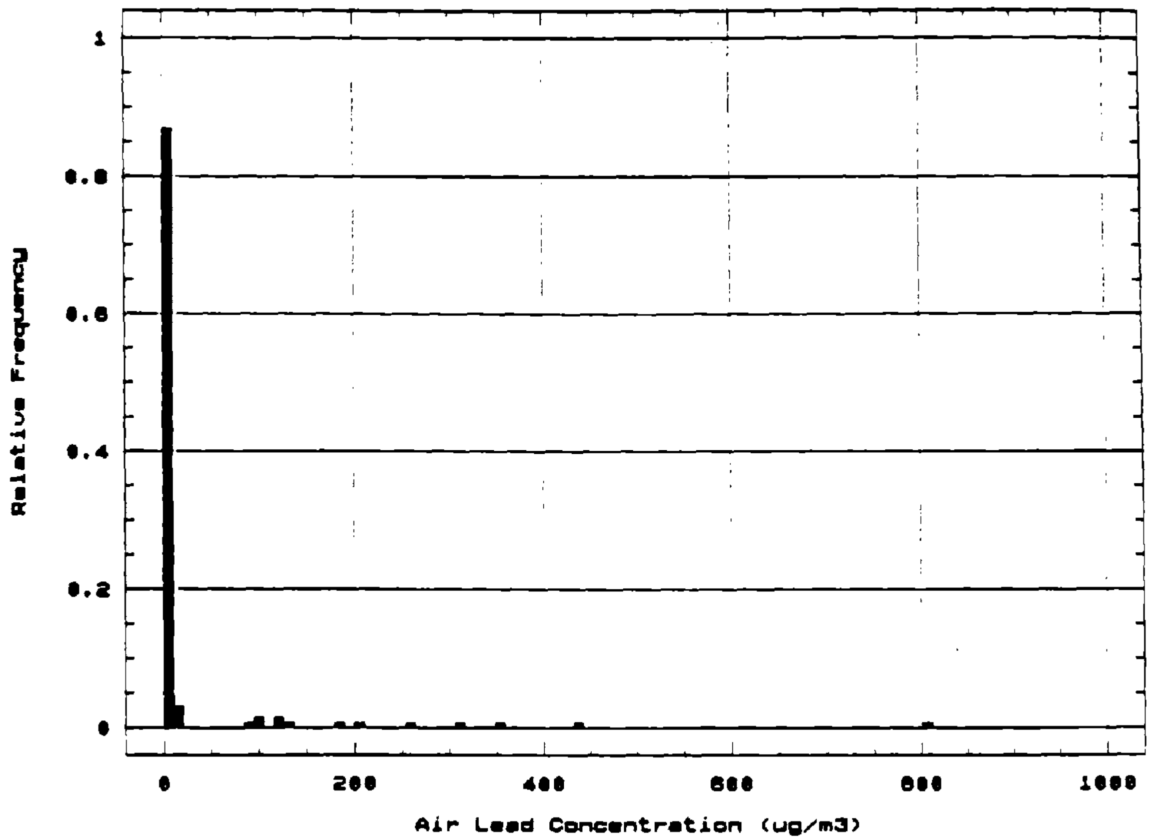


Figure 2. AIR LEAD CONCENTRATIONS
(Radiator Repair Area By Shop)

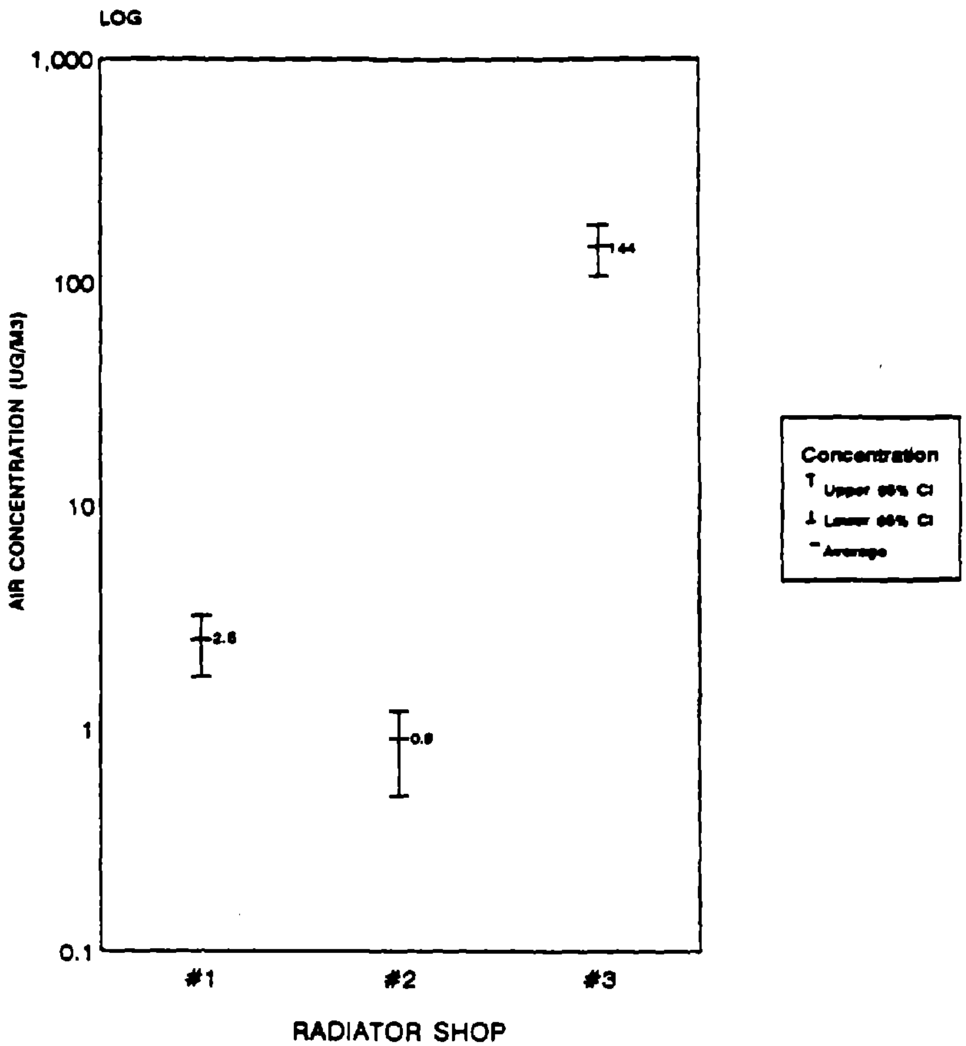


Figure 3
Frequency Histogram: TWA8 Exposures

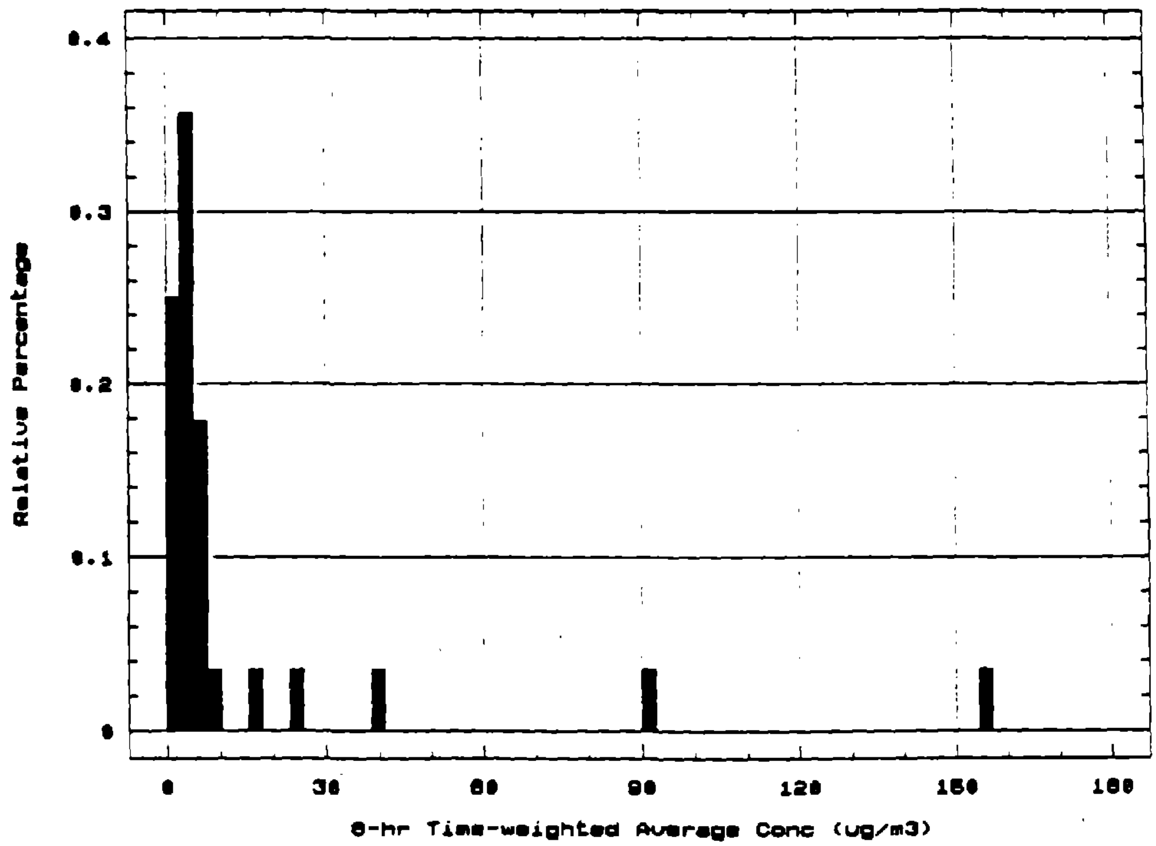


Figure 4. TIME-WEIGHTED AVERAGE (8-HR) EXPOSURES
(Radiator Repair Mechanics by Shop)

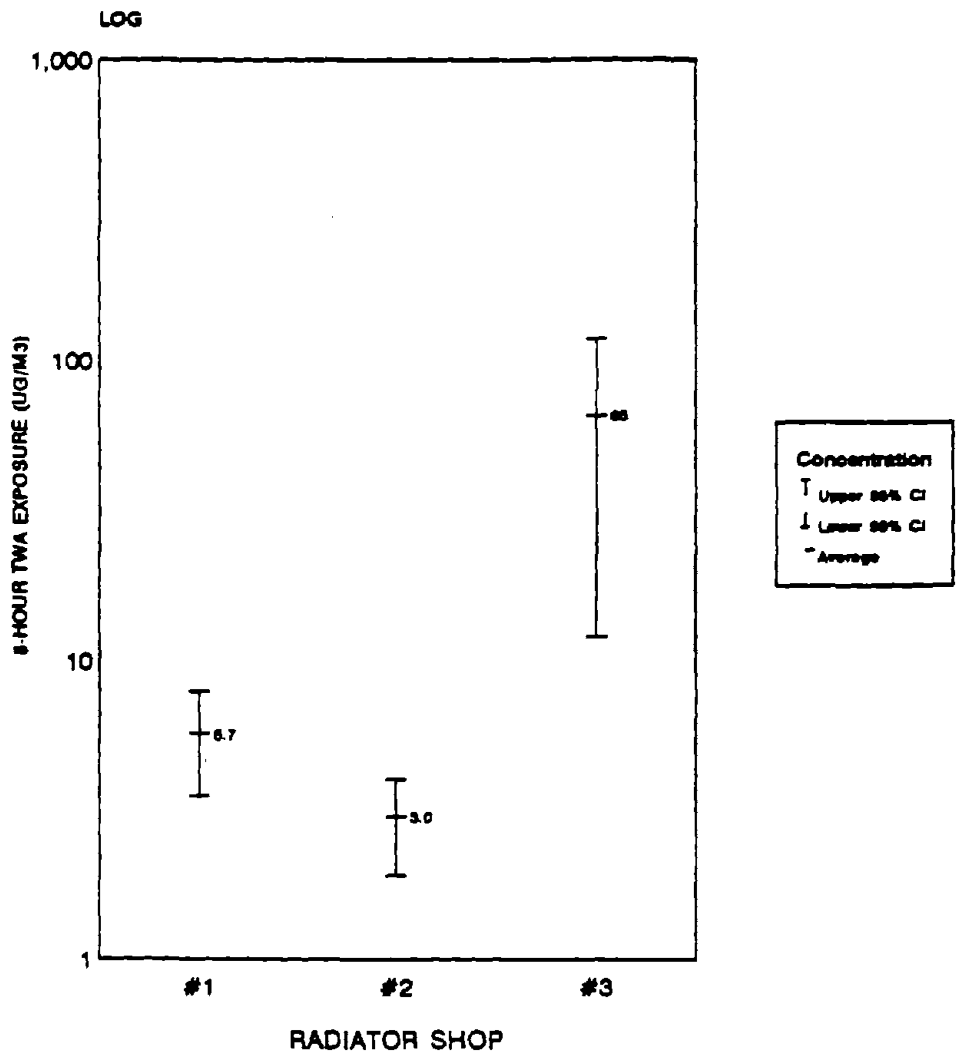


Figure 5. TIME-WEIGHTED AVERAGE (8-HR) EXPOSURES
(ARITHMETIC MEANS BY WORKER)

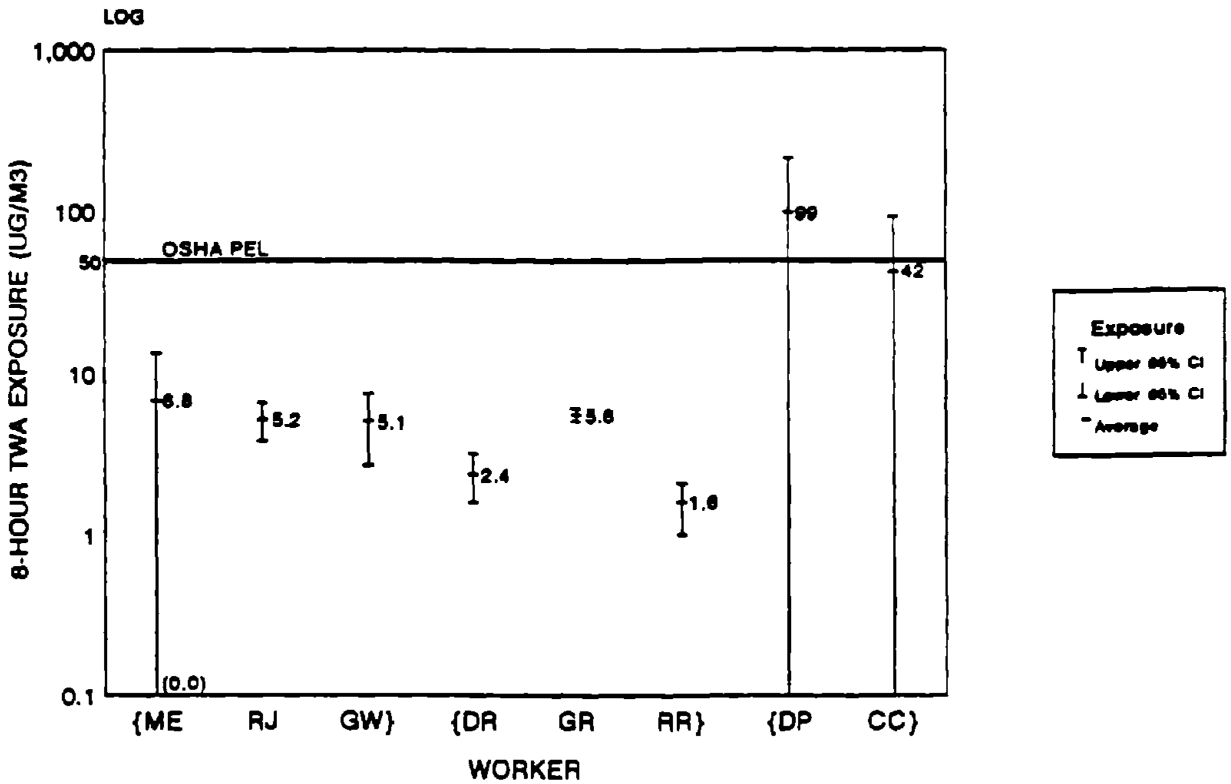


FIGURE 6. PLOT OF INDIVIDUAL TIME-WEIGHTED AVERAGE (8-HR) EXPOSURES
(BY SHOP BY WORKER BY DAY)

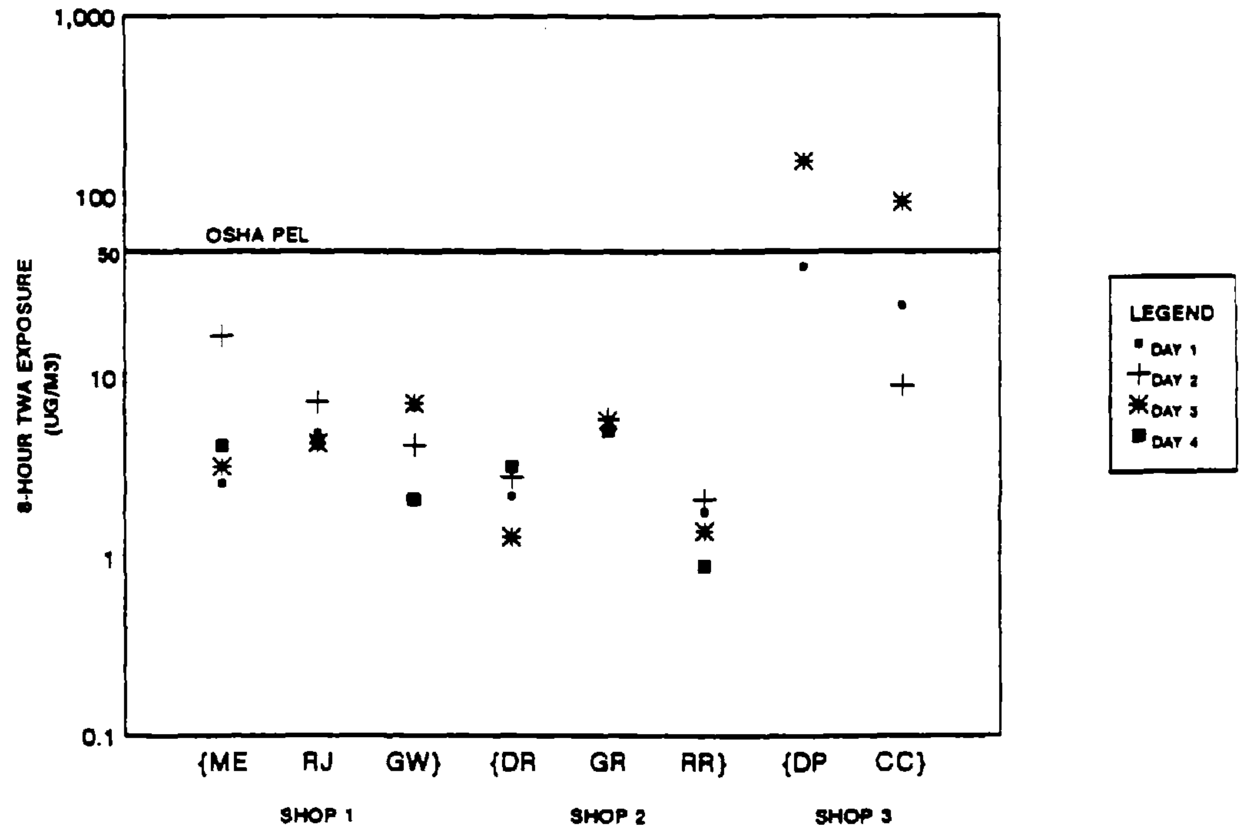


Figure 7
Frequency Histogram: PbS Concentrations

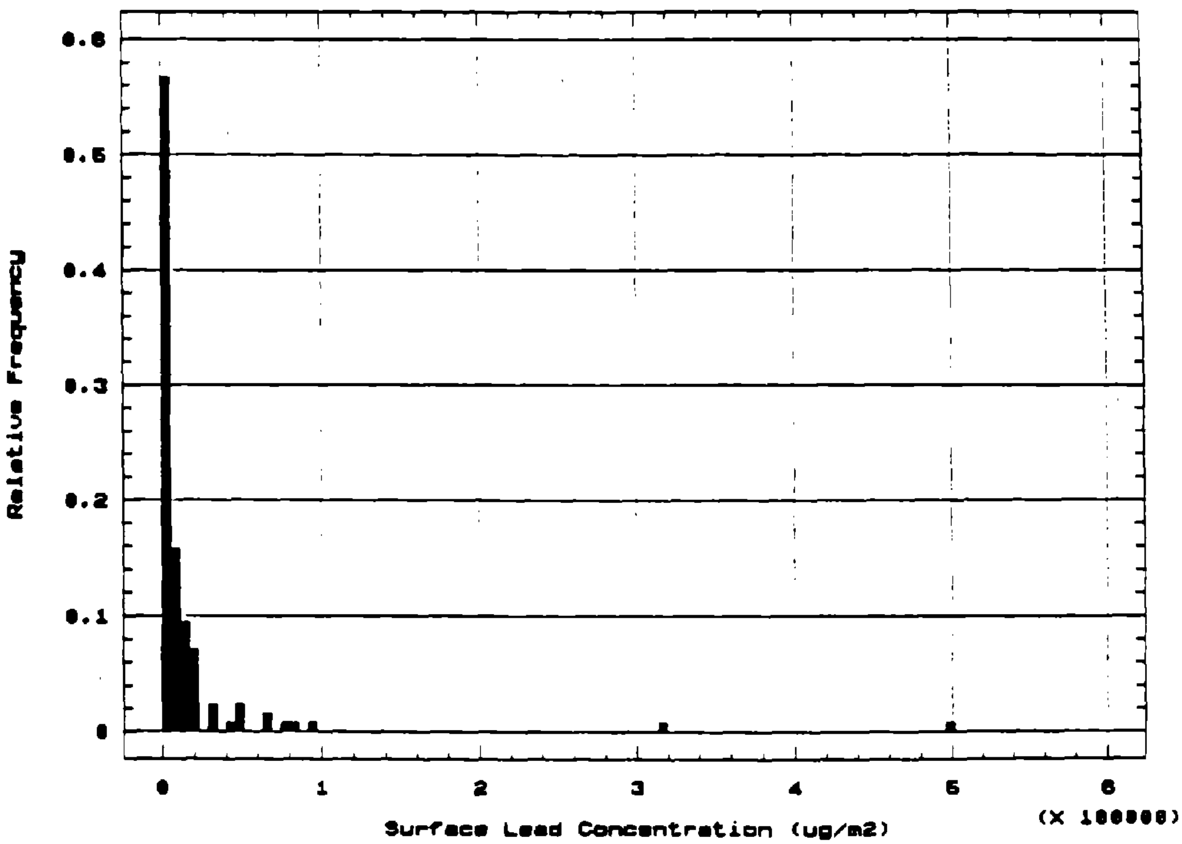


Figure 8. SURFACE LEAD CONTAMINATION
(All Radiator Shops by Area)

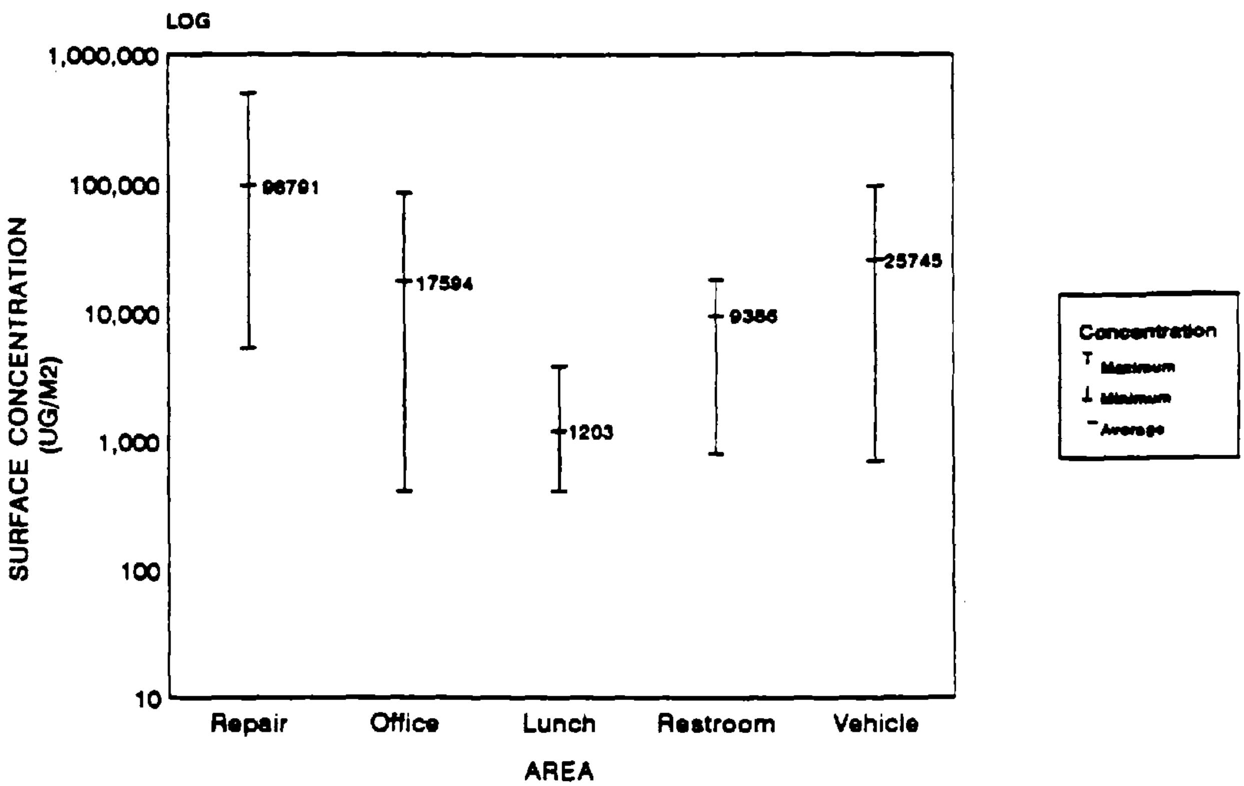


Figure 9. LEAD CONTAMINATION OF WORKER'S HANDS
(Radiator Mechanics and Helpers* by Worker)

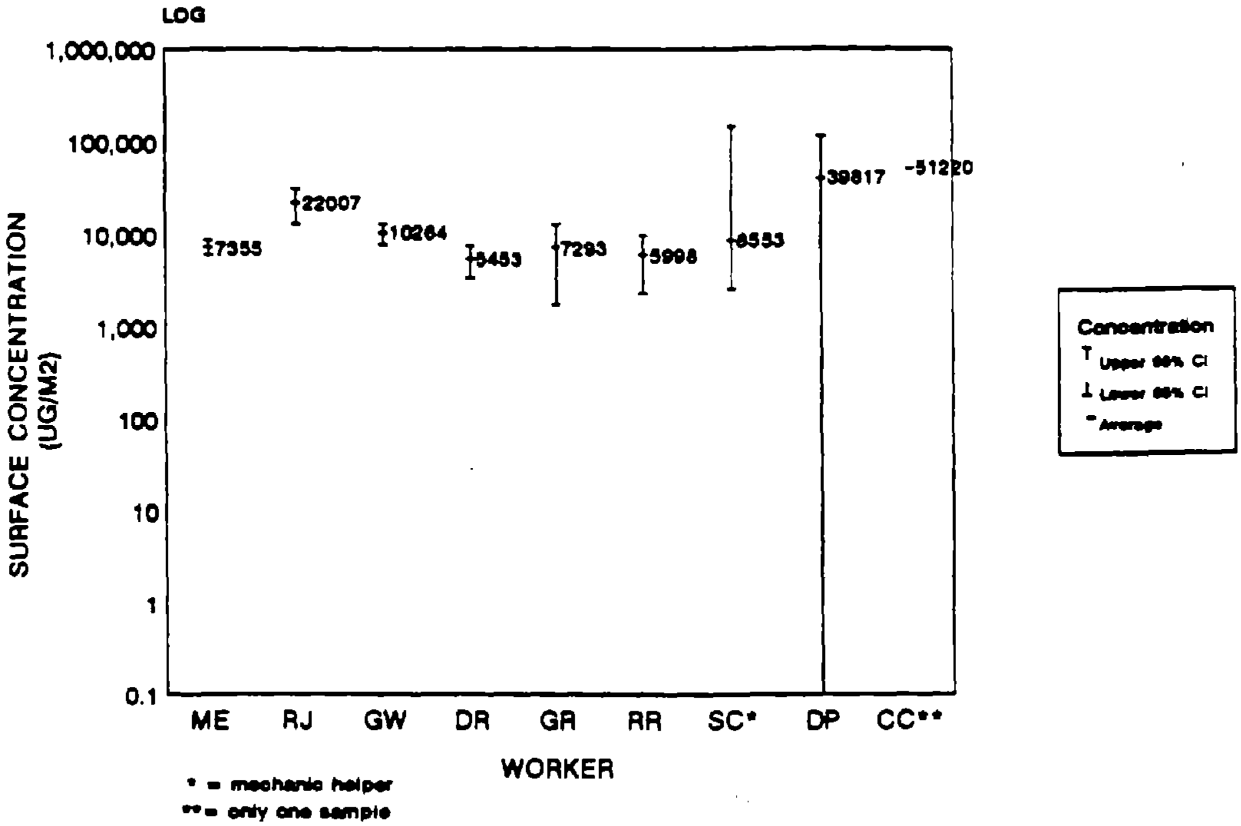


Figure 10. LEAD CONTAMINATION OF HANDS: Before vs. After Washing
(Shop #2: Radiator Mechanics and Helpers* by Worker)

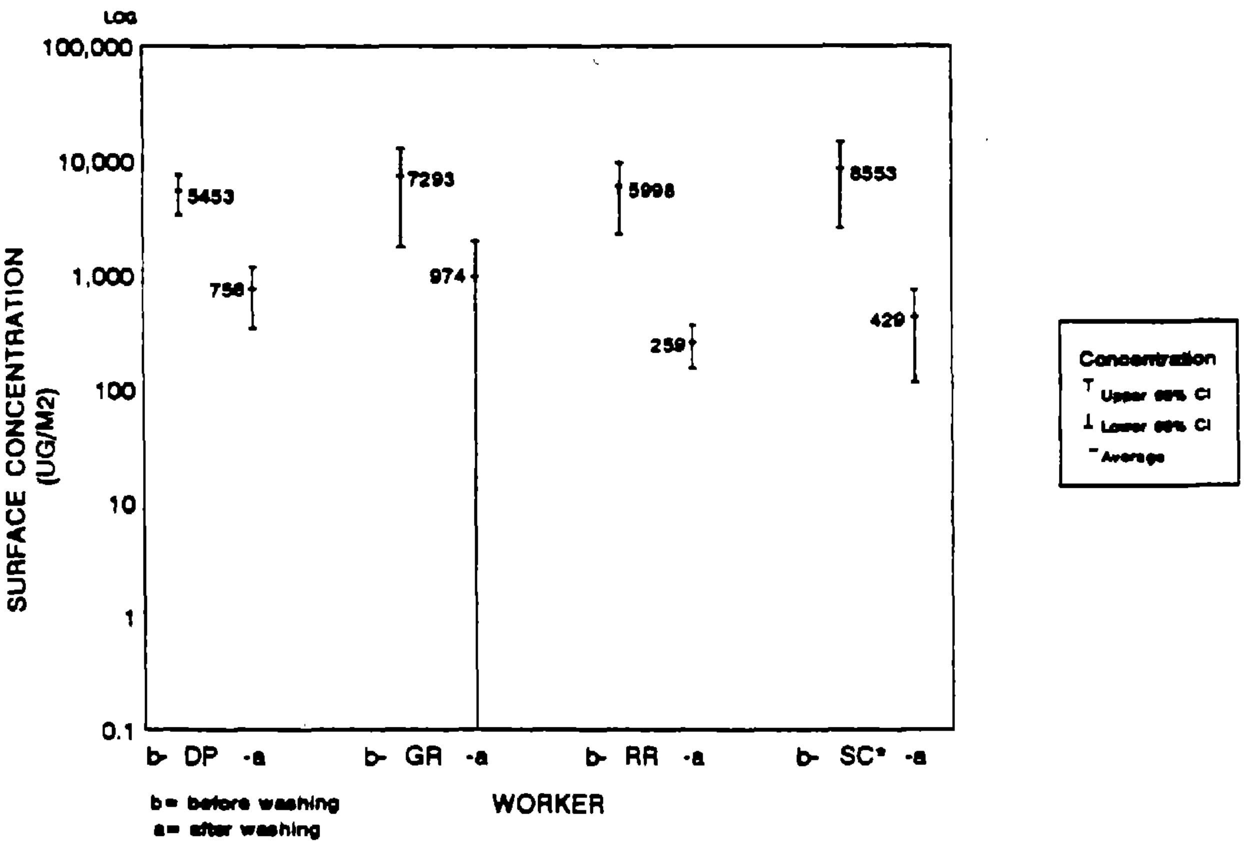


Figure 11. LEAD CONTAMINATION OF HANDS: Before vs. After Washing
(Shop #2: All Radiator Mechanics and Helpers*)

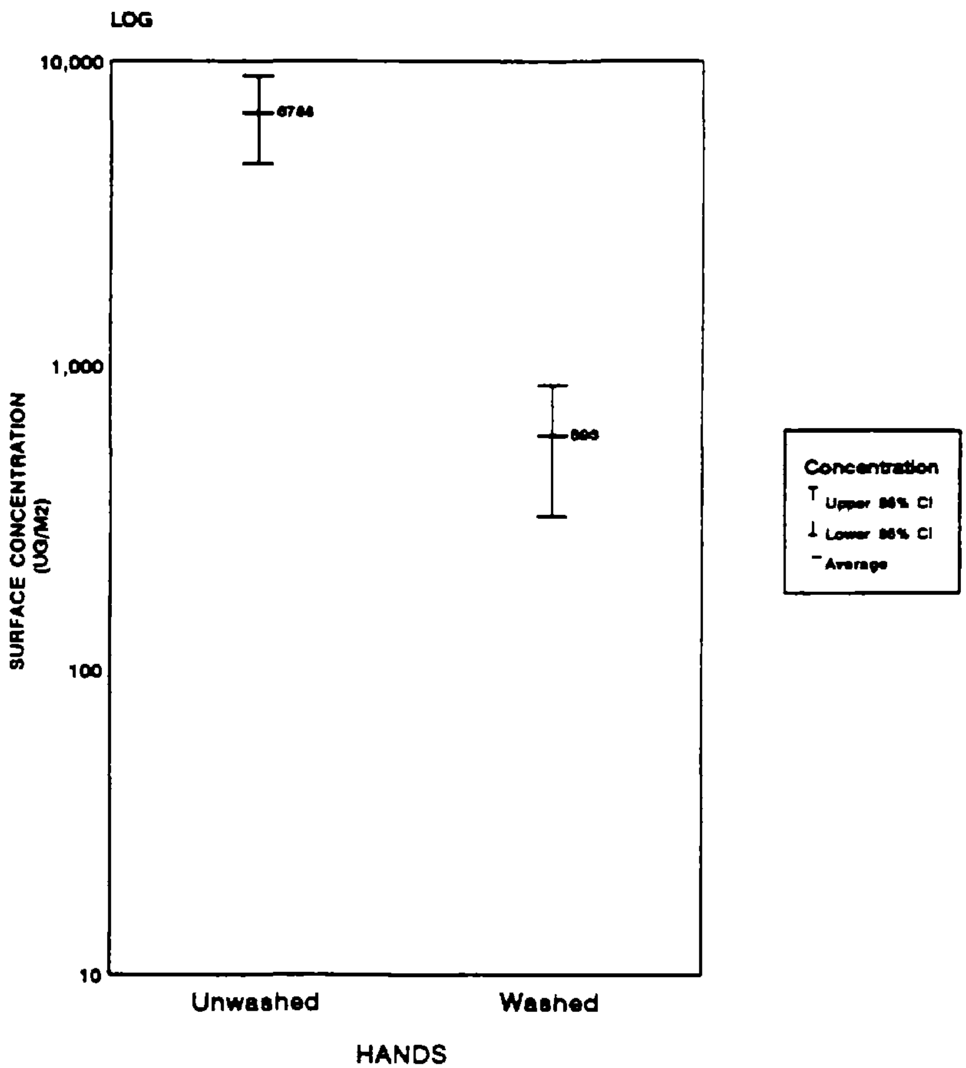


FIGURE 12. LEAD AEROSOL DISTRIBUTIONS
Radiator Repair Shop #1

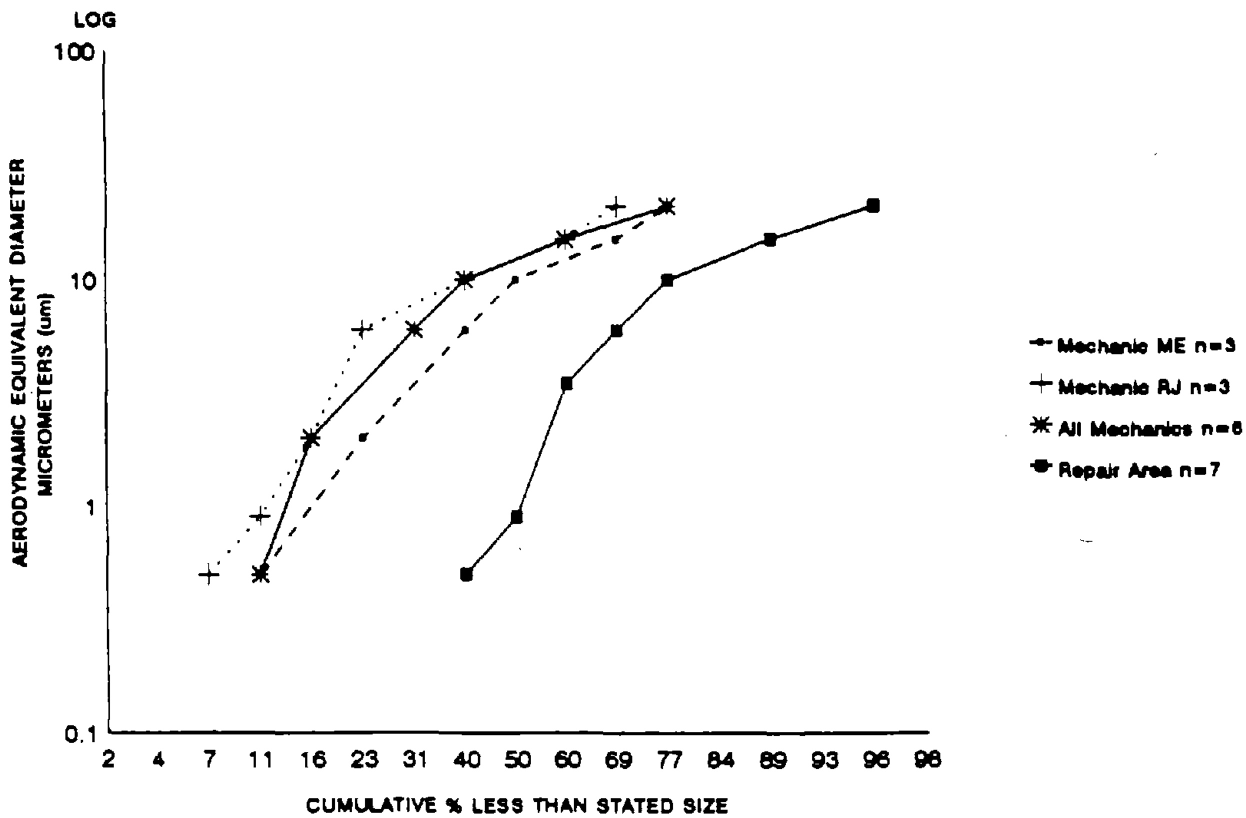


FIGURE 13. LEAD AEROSOL DISTRIBUTIONS

Radiator Repair Shop #2

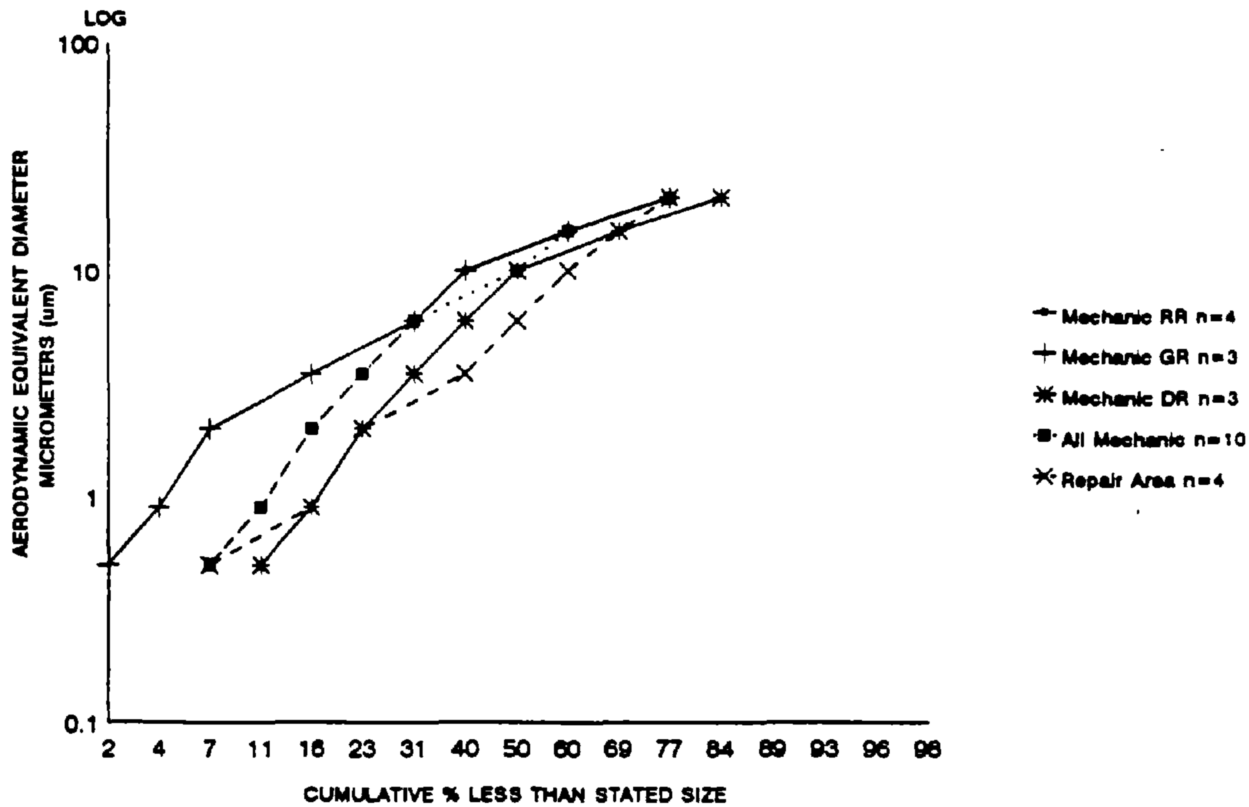


FIGURE 14. LEAD AEROSOL DISTRIBUTIONS
Radiator Repair Shop #3

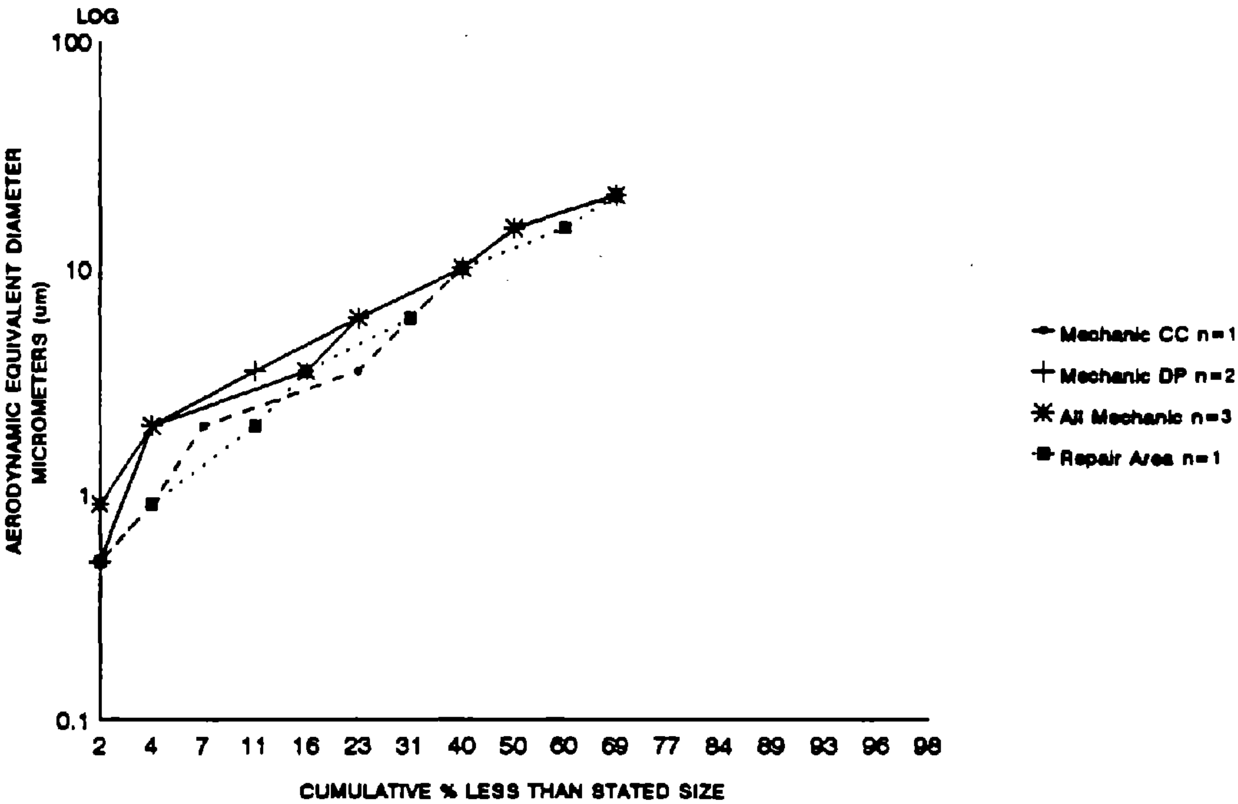
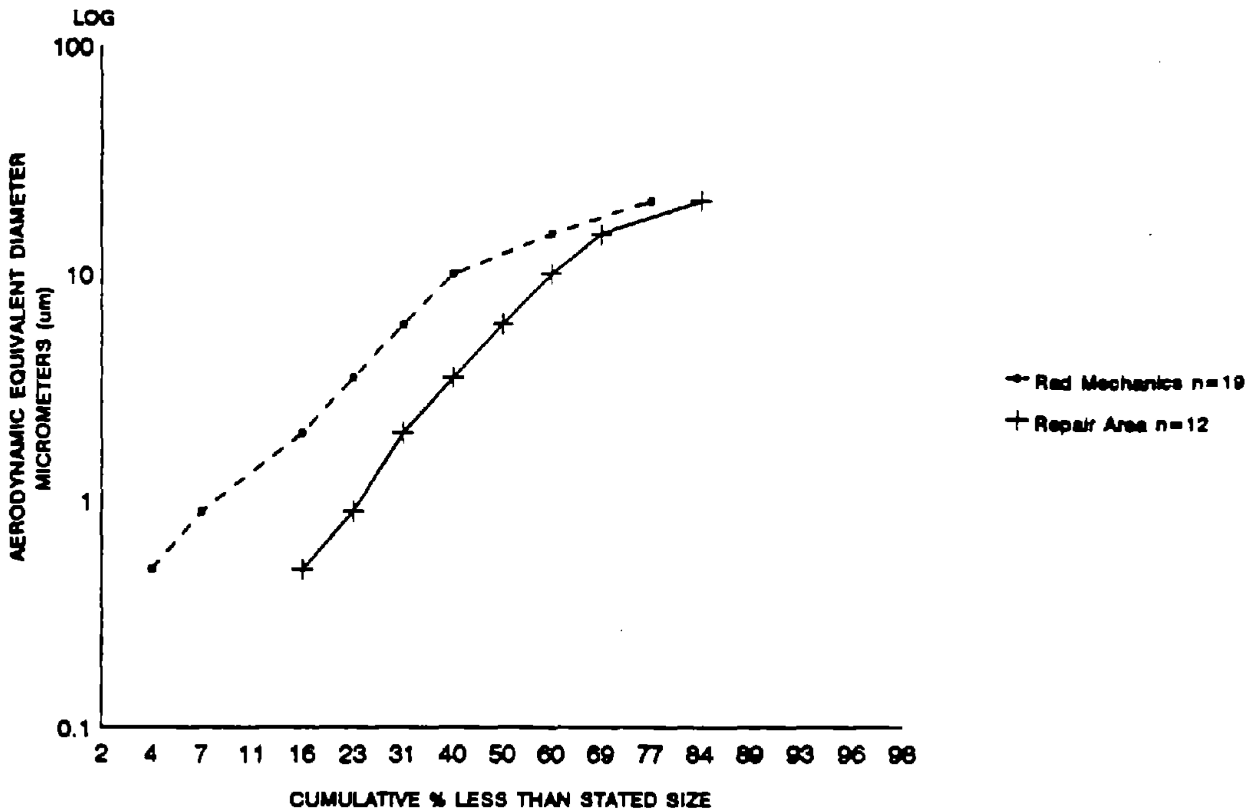


FIGURE 15. LEAD AEROSOL DISTRIBUTIONS

All Radiator Repair Shops



APPENDIX A Introductory Letter to Radiator Shop Owners

Introductory Letter to Radiator Shops (SAMPLE)

March 20, 1991

Radiator Shop Name
Street
City, State Zip

The National Institute for Occupational Safety and Health (NIOSH) with involvement from the University of Cincinnati's Institute of Environmental Health is conducting a research study of lead hazards in the radiator repair industry. The primary sources of lead exposures in radiator shops include the inhalation of lead fumes during soldering and burning and the accidental ingestion of lead from contaminated surfaces. State and Federal occupational health programs have identified radiator shops to have a high incidence of over-exposures to lead and yet, as small businesses, to have limited resources for hazard recognition, evaluation, and control (see enclosed article from the Morbidity and Mortality Weekly Report, March 1, 1991).

The purpose of this study is to measure worker exposures to lead and to evaluate existing methods for reducing lead levels. Lead will be measured in radiator shops during a five-day survey by collecting: 1) air samples worn by personnel and also placed in work areas; and 2) wipe samples from workers' hands and face and also from work surfaces. The results of the survey will be reported to the participating shop and will include specific recommendations for effective and practical methods to reduce exposures, if necessary.

The primary benefit of this survey to you as an employer is the evaluation of any lead exposures in your shop. Lead is a serious health hazard which can cause damage to the brain, blood, nerves, kidneys, and reproductive organs and may result in permanent disability. The economic costs of lead problems are substantial (including medical bills, workers' comp claims, lost work time, low productivity, and OSHA penalties). Therefore, recognizing and controlling lead exposures are important for protecting workers' health as well as reducing business expenses. Our survey results will determine whether your company has a lead problem and provide specific guidelines for better protecting your workers. Previous NIOSH studies in radiator shops have been recognized by the National Automotive Radiator Service Association (see Automotive Cooling Journal, May 1990).

Prior to selecting shops for field surveys, preliminary information is needed from radiator shops in the greater Cincinnati area. Please complete the enclosed information form by April 5, 1991 and return in the stamped, pre-addressed envelope. After this preliminary information has been analyzed, a sample of 3-5 shops will be selected for an on-site visit by industrial hygienists. If you are selected to be visited, I will contact you by telephone to make arrangements for scheduling a five-day survey between June and September.

This survey is authorized by the Occupational Safety and Health Act of 1970. NIOSH regards your participation to be essential and appreciates your prompt response to this request. If you have any questions regarding this study, or would like to receive a copy of the complete study protocol, please write or call me at (513) 841-4314. Thank you for your cooperation.

Sincerely,

Greg M. Piacitelli, CIH
Project Officer
Industrywide Studies Branch
Division of Surveillance, Hazard
Evaluations, and Field Studies

Attachment

NIOSH/UC Study of Lead in Radiator Repair Shops

Request for Information

Date: ___/___/___

Company Name: ____

Street: ____

City, State, Zip: ____

Phone:(___) ____________________________________

Company owner: ____

Street: ____

City, State, Zip: ____

Phone:(___) ____________________________________

Name of person completing this form: ____________________________

Title: ____________________________

Phone:(___) ________________________

If any workers at this company are represented by a labor union, complete:

Union Name & Local #: ____________________________________

Street: ____

City, State, Zip: ____

Phone:(___) ____________________________________

Union Representative: ____________________________________

☛ Do you solder radiators in your shop? (circle one) Yes No

If yes, does the solder used contain any lead? Yes No Uncertain

Provide information on the solder (e.g. supplier, product name, contents):

If no to either question, simply return this page in the enclosed stamped envelope. Thank you. Otherwise, please continue and complete the following information.

1. Is radiator service your primary business?_____
If no, what other activities do you perform at your facility?

2. Number of radiator repair stations:________

3. Number of radiator repair mechanics:_____ (full-time)
_____ (part-time)

4. Number of other employees:

Job Title	Number
______	___
______	___
______	___
______	___
______	___
______	___
______	___

5. Average number of radiators soldered per day, per week, or per month (be as specific as possible): ___ per ___ (currently)
___ per ___ (during peak repair season)

6. Are any engineering controls (such as ventilation hoods) used for controlling lead? ____ If so, describe what type(s):

7. Is personal protective equipment (such as respirators) provided to workers? ___
If so, describe what type(s):

8. Have air samples for lead ever been collected at this shop?_____
If yes, complete the following:

	When	Who	Records Available?
(example)	1988	OSHA	yes

9. Have blood lead levels ever been determined for employees at this shop?_____
If yes, complete the following:

	When	Who	Records Available?
(example)	1990	Biolab, Inc	yes

Other comments:

Thank you for your full cooperation. Please return this form in the enclosed stamped envelope to:

Greg M. Piacitelli, CIH
NIOSH/DSHEFS/IWSB/IHS
MS R-14
4676 Columbia Parkway
Cincinnati, Ohio 45226

APPENDIX B Follow-up Letter to Non-Respondent Radiator Shop Owners

Follow-up Letter to Non-Respondents (SAMPLE)

May 2, 1991

Radiator Shop Name
Street
City, State Zip

Recently, we requested your company's participation in a mail survey about potential exposures to lead. To date, we have not received your reply. We recognize that mail delivery or your business schedule may have delayed your response and we have therefore enclosed a duplicate of our original letter, dated March 20, 1991.

As the letter states, the data gathered from mail questionnaires will be used to assess the extent of lead exposures in radiator shops in the Cincinnati area and to better plan a field survey of a limited number of shops. Your completion of the information form does not mean that your shop will or will not be chosen for a future sampling survey. However, your cooperation will help ensure that a worthwhile study be conducted.

As explained in the original letter, this survey is authorized by the Occupational Safety and Health Act of 1970. NIOSH prefers your voluntary participation but reserves the right under this Act to issue and enforce administrative subpoenas for the information. Please have the appropriate person complete the enclosed information form by May 17, 1991 and return in the stamped, pre-addressed envelope. Your complete and prompt response to this request is greatly appreciated. If you have any questions regarding this study, or would like to receive a copy of the complete study protocol, please write or call me at (513) 841-4314. Thank you for your cooperation.

Sincerely,

Greg M. Piacitelli, CIH
Project Officer
Industrywide Studies Branch
Division of Surveillance, Hazard
Evaluations, and Field Studies

APPENDIX C Letter Arranging Site Visit Survey

Letter for Arranging Site Visit (SAMPLE)

July 2, 1991

Radiator Shop Name
Street
City, State Zip

Thank you for your recent response to our request for information concerning lead usage at your radiator repair shop. The information has been included with that from other repair shops and is useful for describing the range of radiator repair businesses in the Cincinnati area.

Based upon your estimated repair volume, degree of workplace controls, and previous monitoring, your shop has been selected for an on-site study to determine exposures to lead. Lead will be measured during a five-day survey by collecting: 1) air samples worn by personnel and also placed in work areas; and 2) wipe samples from workers' hands and face and also from work surfaces.

As pointed out earlier, the primary benefit of this survey to you as an employer is the no-cost evaluation of lead exposures in your shop. Since the economic costs of lead problems are substantial, recognizing and controlling lead exposures are important for protecting workers' health as well as reducing business expenses. Our survey results will determine whether your company has a lead problem and provide specific guidelines for better protecting your workers.

The survey at your facility has been tentatively scheduled for July 29-August 2. Prior to conducting the actual survey, I would like to visit your shop to observe the repair activities and to discuss the survey procedures. Therefore, I will be calling you soon to arrange a meeting with you at your shop within the next couple of weeks.

If you have any questions, please feel free to call me at (513) 841-4314. Your cooperation in this project is greatly appreciated.

Sincerely,

Greg M. Piacitelli, CIH
Project Officer
Industrywide Studies Branch
Division of Surveillance, Hazard
Evaluations, and Field Studies

APPENDIX D NIOSH Sampling and Analytical Method 7082

FORMULA: Pb

LEAD

METHOD: 7082
ISSUED: 2/15/84

M.W.: 207.19 (Pb); 223.19 (PbO)

OSHA: 0.05 mg/m³
NIOSH: 0.05 mg/m³ [1]
ACGIH: 0.15 mg/m³; STEL 0.45 mg/m³

PROPERTIES: soft metal;
d 11.3 g/cm³; MP 327.5 °C;
valences +2, +4 in salts

SYNONYMS: vary depending upon the chemical form (elemental lead and lead compounds except alkyl lead); CAS #1317-36-8 (PbO); CAS #7439-92-1 (Pb).

SAMPLING	MEASUREMENT
SAMPLER: FILTER (0.8-µm cellulose ester membrane)	TECHNIQUE: ATOMIC ABSORPTION, FLAME
FLOW RATE: 1 to 4 L/min	ANALYTE: lead
VOL-MIN: 200 L @ 0.05 mg/m³ -MAX: 1200 L	ASHING: conc. HNO_3, 6 mL; 140 °C
SHIPMENT: routine	FINAL SOLUTION: 10% HNO_3, 10 mL
SAMPLE STABILITY: stable	FLAME: air-acetylene, oxidizing
BLANKS: 2 to 10 field blanks per set	WAVELENGTH: 283.3 nm
	BACKGROUND CORRECTION: D_2 or H_2 lamp
ACCURACY	CALIBRATION: Pb^{++} in 10% HNO_3
RANGE STUDIED: 0.13 to 0.4 mg/m³ [2]; 0.15 to 1.7 mg/m³ (fume) [3]	RANGE: 10 to 200 µg per sample [3,8]
BIAS: not significant [2]	ESTIMATED LOD: 2.6 µg per sample [9]
OVERALL PRECISION (s_r): 0.072 [2]; 0.068 (fume) [3]	PRECISION (s_r): 0.03 [2]

APPLICABILITY: The working range is 0.025 to 0.5 mg/m³ for a 400-L air sample. The method is applicable to elemental lead, including Pb fume, and all other aerosols containing lead. This is an elemental analysis, not compound specific. Aliquots of the samples can be analyzed separately for additional elements.

INTERFERENCES: Use D_2 or H_2 continuum background correction to control flame or molecular absorption. High concentrations of calcium, sulfate, carbonate, phosphate, iodide, fluoride, or acetate can be corrected.

OTHER METHODS: This method combines and replaces P&CAM 173 [8] and S341 [7,9] for lead. Method 7300 (ICP-AES) is an alternate analytical method.Method 7505 is specific for lead sulfide. The following have not been revised: the dithizone method, which appears in P&CAM 102 [4] and the lead criteria document [1]; P&CAM 191 (ASV) [5]; and P&CAM 214 (graphite furnace-AAS) [6].

REAGENTS:

1. Nitric acid, conc.
2. Nitric acid, 10% (w/v). Add 100 mL conc. HNO_3 to 500 mL water; dilute to 1 L.
3. Hydrogen peroxide, 30% H_2O_2 (w/w), reagent grade.
4. Calibration stock solution, 1000 µg Pb/mL. Commercial standard or dissolve 1.00 g Pb metal in minimum volume of (1+1) HCl and dilute to 1 L with 1% (v/v) HCl. Store in a polyethylene bottle. Stable ≥ one year.
5. Air, compressed, filtered.
6. Acetylene.
7. Distilled or deionized water.

EQUIPMENT:

1. Sampler: Cellulose ester filter, 0.8-µm pore size, 37-mm diameter; in cassette filter holder.
2. Personal sampling pump, 1 to 4 L/min, with flexible connecting tubing.
3. Atomic Absorption Spectrophotometer with an air-acetylene burner head.
4. Lead hollow cathode lamp or electrode dischargeless lamp.
5. Regulators, two-stage, for air and acetylene.
6. Beakers, Phillips, 125 mL, or Griffin, 50 mL with watchglass covers.*
7. Volumetric flasks, 10- and 100-mL.*
8. Assorted volumetric pipets as needed.*
9. Hotplate, surface temperature 140° C.
10. Bottles, polyethylene, 100-mL.

*Clean all glassware with conc. nitric acid and rinse thoroughly with distilled or deionized water before use.

SPECIAL PRECAUTIONS: Perform all acid digestions in a fume hood.

SAMPLING:

1. Calibrate each personal sampling pump with a representative sampler in line.
2. Sample at an accurately known flow rate between 1 and 4 L/min for up to 8 hrs for TWA measurements. Do not exceed a filter loading of ca. 2 mg total dust.

SAMPLE PREPARATION:

NOTE: The following sample preparation gave quantitative recovery (see EVALUATION OF METHOD) [9]. Steps 4 through 9 of Method 7300 or other quantitative ashing techniques may be substituted, especially if several metals are to be determined on a single filter.

3. Open the cassette filter holders and transfer the samples and blanks to clean beakers.
4. Add 3 mL conc. HNO_3, and 1 mL 30% H_2O_2 and cover with a watchglass. Start reagent blanks at this step.
   NOTE: If PbO_2 is not present in the sample, the 30% H_2O_2 need not be added [3,9].
5. Heat on hotplate (140 °C) until most of the acid has evaporated.
6. Repeat two more times using 2 mL conc. HNO_3 and 1 mL 30% H_2O_2 each time.
7. Heat on 140 °C hotplate until a white ash appears.
8. When sample is dry, rinse the watchglass and walls of the beaker with 3 to 5 mL 10% HNO_3. Allow the solution to evaporate to dryness.
9. Cool each beaker and dissolve the residues in 1 mL conc. HNO_3.
10. Transfer the solution quantitatively to a 10-mL volumetric flask and dilute to volume with distilled water.
    NOTE: If the concentration ($\underline{M}$) of any of the following is expected to exceed the lead concentration ($\underline{M}$) by 10-fold or more, add 1 mL 1 $\underline{M}$ Na_2EDTA to each flask before dilution to volume: $CO_3^{=}$, $PO_4^{\equiv}$, I^-, F^-, CH_3COO^-. If Ca^{++} or $SO_4^{=}$ are present in 10-fold excess, make all standards and samples 1% (w/w) in La^{++} [8].

CALIBRATION AND QUALITY CONTROL:

11. Prepare a series of working standards covering the range 1 to 20 µg Pb/mL (1 to 200 µg Pb per sample) by adding aliquots of calibration stock solution to 100-mL volumetric flasks. Dilute to volume with 10% HNO_3. Store the working standards in polyethylene bottles and prepare fresh weekly.
12. Analyze the working standards together with the blanks and samples (steps 17 and 18).
13. Prepare a calibration graph of absorbance vs. solution concentration (µg/mL).
14. Aspirate a standard for every 10 samples to check for instrument drift.
15. Check recoveries with at least one spiked media blank per 10 samples.
16. Use method of additions occasionally to check for interferences.

MEASUREMENT:

17. Set spectrophotometer as specified by the manufacturer and to conditions on page 7082-1.
    NOTE: An alternate wavelength is 217.0 nm [10]. Analyses at 217.0 nm have slightly greater sensitivity, but poorer signal-to-noise ratio compared to 283.3 nm. Also, non-atomic absorption is significantly greater at 217.0 nm, making the use of D_2 or H_2 continuum background correction mandatory at that wavelength.
18. Aspirate standards, samples, and blanks. Record absorbance readings.
    NOTE: If the absorbance values for the samples are above the linear range of the standards, dilute with 10% HNO_3, reanalyze, and apply the appropriate dilution factor in the calculations.

CALCULATIONS:

19. Using the measured absorbances, calculate the corresponding concentrations (µg/mL) of lead in the sample, C_s, and average media blank, C_b, from the calibration graph.
20. Using the solution volumes (mL) of the sample, V_s, and media blanks, V_b, calculate the concentration, C (mg/m³), of lead in the air volume sampled, V (L):

$$C = \frac{C_s V_s - C_b V_b}{V}, \text{ mg/m}^3.$$

EVALUATION OF METHOD:

Method S241 [7] was issued on October 24, 1975, and validated over the range 0.13 to 0.4 mg/m³ for a 180-L air sample, using generated atmospheres of lead nitrate [2]. Recovery in the range 18 to 72 µg Pb per sample was 98%, and collection efficiency of 0.8-µm mixed cellulose ester filters (Millipore Type AA) was 100% for the aerosols. Subsequent studies on analytical recovery of 200 µg Pb per sample gave the results [3,9]:

Species	Digestion Method	Analytical Recovery, %
Pb metal	HNO_3 only	92 ± 4
Pb metal	$HNO_3 + H_2O_2$	103 ± 3
PbO	HNO_3 only	93 ± 4
PbS	HNO_3 only	93 ± 5
PbO_2	HNO_3 only	82 ± 3
PbO_2	$HNO_3 + H_2O_2$	100 ± 1
Pb in paint*	HNO_3 only	95 ± 6
Pb in paint*	$HNO_3 + H_2O_2$	95 ± 6

*Standard Reference Material #1579, U.S. National Bureau of Standards.

Additional collection efficiency studies were also done using Gelman GN-4 filters for the collection of Pb fume, which had geometric mean diameter of 0.1 µm [3]. Mean collection efficiency for 24 sampling runs at flow rates between 0.15 and 4.0 L/min was >97 ± 2%. Overall precision, s_r, was 0.072 for lead nitrate aerosol [2,7] and 0.068 for Pb fume [3,9].

REFERENCES:

[1] Criteria for a Recommended Standard...Occupational Exposure to Inorganic Lead (Revised Criteria), U.S. Department of Health, Education, and Welfare, Publ. (NIOSH) 78-158 (1978).
[2] Documentation of the NIOSH Validation Tests, U.S. Department of Health, Education, and Welfare, Publ. (NIOSH) 77-185 (1977).
[3] Heavy Metal Aerosols: Collection and Dissolution Efficiencies, Final Report of NIOSH Contract 210-79-0058, W. F. Gutknecht, M. H. Ranade, P. M. Grohse, A. Damle, and D. O'Neal, Research Triangle Institute; available as Order No. PB 83-106740 from NTIS, Springfield, VA 22161 (1981).
[4] NIOSH Manual of Analytical Methods, 2nd. ed., V. 1, P&CAM 102, U.S. Department of Health, Education, and Welfare, Publ. (NIOSH) 77-157-A (1977).
[5] Ibid, P&CAM 191.
[6] Ibid, P&CAM 214.
[7] Ibid., V. 3, S341, U.S. Department of Health, Education, and Welfare, Publ. (NIOSH) 77-157-C (1977).
[8] Ibid, V. 5, P&CAM 173, U.S. Department of Health, Education, and Welfare, Publ. (NIOSH) 77-157-A (1979).
[9] Ibid, V. 7, S341 (revised 3/25/81), U.S. Department of Health and Human Services, Publ. (NIOSH) 82-100 (1982).
[10] Analytical Methods for Atomic Absorption Spectrophotometry, Perkin-Elmer (1976).

METHOD REVISED BY: Mark Millson and R. DeLon Hull, NIOSH/DPSE; S341 originally validated under NIOSH Contract CDC-94-74-45; additional studies under NIOSH Contract 210-79-0058.

APPENDIX E NIOSH Sampling and Analytical Method 7105

FORMULA: Pb

LEAD

METHOD: 7105

M.W.: 207.19 (Pb); 223.19 (PbO)

ISSUED: 8/15/90

OSHA: 0.05 mg/m^3
NIOSH: <0.1 mg/m^3 [1]
ACGIH: 0.15 mg/m^3

PROPERTIES: soft metal; d 11.3 g/cm^3; MP 327.5 °C; valences +2, +4 in salts

SYNONYMS: vary depending upon the chemical form (elemental lead and lead compounds except alkyl lead); CAS #7439-92-1 (Pb); CAS #1317-36-8 (PbO).

SAMPLING

SAMPLER: FILTER (0.8-µm cellulose ester membrane)

FLOW RATE: 1 to 4 L/min

VOL-MIN: 1 L @ 0.05 mg/m^3
-MAX: 1500 L

SHIPMENT: routine

SAMPLE STABILITY: stable

FIELD BLANKS: 10% of samples

ACCURACY

RANGE STUDIED: not studied

BIAS: not significant [2]

OVERALL PRECISION (s_r): not determined

MEASUREMENT

TECHNIQUE: ATOMIC ABSORPTION, GRAPHITE FURNACE

ANALYTE: lead

ASHING: conc. HNO_3, 3 mL; 30% H_2O_2, 1 mL; 140 °C

FINAL SOLUTION: 10 mL 5% HNO_3

WAVELENGTH: 283.3 nm

GRAPHITE TUBE: pyrolytic coated

INJECTION: 20 µL + 10 µL matrix modifier,
DRY: 110 °C, 70 sec;
CHAR: 800 °C, 30 sec;
ATOMIZE: 1800 °C, 5 sec.

BACKGROUND CORRECTION: D_2, H_2 or Zeeman

CALIBRATION: Pb^{++} in 5% HNO_3

RANGE: 0.05 to 1.0 µg per sample [2]

ESTIMATED LOD: 0.01 µg per sample [2]

PRECISION (s_r): not determined

APPLICABILITY: The working range is 0.0002 to >1 mg/m^3 for a 200-L air sample. If high concentrations are expected, the samples should be analyzed by flame AAS. The method is applicable to elemental lead, including Pb fume, and all other aerosols containing lead. This is an elemental analysis, not compound-specific. Aliquots of the sample may be analyzed separately for additional elements.

INTERFERENCES: Use D_2 or H_2 continuum or Zeeman background correction to control molecular absorption. High concentrations of calcium, sulfate, carbonate, phosphate, iodide, fluoride, or acetate can be offest by an additional sample treatment step.

OTHER METHODS: This revises and replaces P&CAM 214 (3). Method 7300 (ICP-AES) is an alternate analytical method. Method 7505 is specific for lead sulfide. Method 7082 is a flame AA method.

REAGENTS:

1. Nitric acid, conc.*
2. Nitric acid, 5% (v/v). Add 50 mL conc. HNO_3 to 500 mL water; dilute to 1 L.
3. Hydrogen peroxide, 30% H_2O_2 (w/w), reagent grade.
4. Calibration stock solution, 1000 µg Pb/mL. Commercial standard or dissolve 1.00 g Pb metal in minimum volume of HNO_3 and dilute to 1 L with 1% (v/v) HNO_3. Store in a polyethylene bottle.
5. Matrix Modifier. Place 0.2 g $NH_4H_2PO_4$ and 0.3 g $Mg(NO_3)_2$ in a 100 mL volumetric flask. Add 2 mL conc. HNO_3 and bring to volume with distilled or deionized water.
6. Argon, prepurified.
7. Distilled or deionized water.

*see SPECIAL PRECAUTIONS

EQUIPMENT:

1. Sampler: Cellulose ester membrane filter, 0.8-µm 37-mm, in 2-piece cassette.
2. Personal sampling pump, 1 to 4 L/min, with flexible connecting tubing.
3. Atomic absorption spectrophotometer with graphite furnace atomizer and background correction.
4. Lead hollow cathode lamp or electrode dischargeless lamp.
5. Regulators, two-stage, for Argon.
6. Beakers, Phillips, 125-mL, or Griffin, 50-mL, with watchglass covers.**
7. Volumetric flasks, 10- and 100-mL.**
8. Assorted volumetric pipets as needed.**
9. Hotplate, surface temperature 140° C.
10. Bottles, polyethylene, 100-mL.

**Clean all glassware with conc. nitric acid and rinse thoroughly with distilled or deionized water before use.

SPECIAL PRECAUTIONS: Conc. nitric acid is an irritant and may burn skin. Perform all acid digestions in a fume hood.

SAMPLING:

1. Calibrate each personal sampling pump with a representative sampler in line.
2. Sample at an accurately known flow rate between 1 and 4 L/min for up to 8 hrs for TWA measurements. Do not exceed a filter loading of ca. 2 mg total dust.

SAMPLE PREPARATION:

3. Open the cassette filter holders and transfer the samples and blanks to clean beakers.
4. Add 3 mL conc. HNO_3, and 1 mL 30% H_2O_2 and cover with a watchglass. Start reagent blanks at this step.
5. Heat on 140 °C hotplate until volume is reduced to about 0.5 mL.
6. Rinse the watchglass and walls of the beaker with 3 to 5 mL 5% HNO_3. Allow the solution to evaporate to 0.5 mL.
7. Cool each beaker.
8. Transfer the solution quantitatively to a 10-mL volumetric flask and dilute to volume with distilled water.

CALIBRATION AND QUALITY CONTROL:

11. Prepare a series of working standards covering the range 0.005 to 0.1 µg Pb/mL (0.05 to 1.0 µg Pb per sample) by adding aliquots of calibration stock solution to 100-mL volumetric flasks. Dilute to volume with 5% HNO_3. Store the working standards in polyethylene bottles and prepare fresh weekly.
12. Analyze the working standards together with the blanks and samples (steps 17 through 19).
13. Prepare a calibration graph of absorbance vs. solution concentration (µg/mL).
14. Analyze a standard for every 10 samples to check for instrument drift.
15. Check recoveries with at least one spiked media blank per 10 samples.

16. Perform a matrix spike of a sample occasionally to check for matrix interferences. If an adequate recovery is not obtained (85 to 115%), an alternate method of analysis should be used, such as flame AA or ICP.

MEASUREMENT:

17. Set spectrophotometer as specified by the manufacturer and to conditions on page 7105-1.
    NOTE: An alternate wavelength is 217.0 nm [6]. Analyses at 217.0 nm have slightly greater sensitivity, but poorer signal-to-noise ratio compared to 283.3 nm. Also, nonatomic absorption is significantly greater at 217.0 nm, making the use of D_2, H_2 continuum, or Zeeman background correction mandatory at that wavelength.
18. Add matrix modifier to samples and standards in proper ratio of 2 to 1 (sample or standard to matrix modifier).
19. Analyze standards, samples, and blanks. Record absorbance readings.
    NOTE: If the absorbance value for the sample is above the linear range of the standards, dilute with 5% HNO_3, reanalyze, and apply the appropriate dilution factor in the calculations.

CALCULATIONS:

20. Using the measured absorbances, calculate/the corresponding concentrations (µg/mL) of lead in the sample, C_s, and average media blank, C_b, from the calibration graph.
21. Using the solution volumes (mL) of the sample, V_s, and media blanks, V_b, calculate the concentration, C (mg/m^3), of lead in the air volume sampled, V (L):

$$C = \frac{C_s V_s - C_b V_b}{V}, \ mg/m^3.$$

EVALUATION OF METHOD:

Method S341 [5] was issued on October 24, 1975, and validated over the range 0.13 to 0.4 mg/m^3 for a 180-L air sample, using generated atmospheres of lead nitrate [2]. Recovery in the range 18 to 72 µg Pb per sample was 98%, and collection efficiency of 0.8-µm mixed cellulose ester filters (Millipore Type AA) was 100% for the aerosols. Subsequent studies on analytical recovery of 200 µg Pb per sample using flame AAS gave the results [3]:

Species	Digestion Method	Analytical Recovery, %
Pb metal	HNO_3 only	92 ± 4
Pb metal	$HNO_3 + H_2O_2$	103 ± 3
PbO	HNO_3 only	93 ± 4
PbS	HNO_3 only	93 ± 5
PbO_2	HNO_3 only	82 ± 3
PbO_2	$HNO_3 + H_2O_2$	100 ± 1
Pb in paint*	HNO_3 only	95 ± 6
Pb in paint*	$HNO_3 + H_2O_2$	95 ± 6

*Standard Reference Material #1579, U.S. National Bureau of Standards.

Additional collection efficiency studies were also done using Gelman GN-4 filters for the collection of Pb fume, which had geometric mean diameter of 0.1 µm [3]. Mean collection efficiency for 24 sampling runs at flow rates between 0.15 and 4.0 L/min was >97 ± 2%. Overall precision, s_r, was 0.072 for lead nitrate aerosol [2,5] and 0.068 for Pb fume [3].

REFERENCES:

[1] NIOSH Recommendations for Occupational Safety and Health Standards. NIOSH, Cincinnati, OH (1988).

[2] Backup Data Report for Method 7105 submitted to NIOSH by DataChem Laboratories, NIOSH (Unpublished, September, 1990).

[3] NIOSH Manual of Analytical Methods, 2nd. ed., V. 1, P&CAM 214, U.S. Department of Health, Education, and Welfare, Publ. (NIOSH) 77-157-A (1977).

[4] Analytical Methods for Atomic Absorption Spectrophotometry, Perkin-Elmer Corporation (1976).

METHOD REVISED BY: James B. Perkins, Brent E. Stephens, and Michael P. Beesley, DataChem, Laboratories, Salt Lake City, Utah. S341 originally validated under NIOSH Contract CDC-94-74-45; additional studies under NIOSH Contract 210-79-0058.

APPENDIX F Field Survey Information Form

NIOSH/UC Study of Lead in Radiator Repair Shops
Field Survey Information Sheet

Name of Shop:______________________________ Date:__________
Address:______________________________ Collected by:__________
____
Phone:(____)______________________________

Shop owner:______________________________
Address:______________________________
____
Phone:(____)______________________________

Survey Contact:______________________________
Title:______________________________
Phone:(____)______________________________

Labor union:______________________________
Address:______________________________
____
Contact:______________________________
Phone:(____)______________________________

Employee Safety and/or Health Representative:
Name:______________________________
Title:______________________________
____

SIC:______________________________

Member of the National Automotive Radiator Service Association (NARSA)?______

1. Are you aware of the existence of the OSHA Lead Standard? _____

If yes, how were you made aware?

Federal OSHA ___
State OSHA ___
State Health Dept ___
Trade Association ___
Other (specify) ___ ____________________

2. Is a copy of the OSHA Lead Standard available at the shop? _____

If yes, where is it kept? __________

3. Are you familiar with specific requirements of the OSHA Lead Standard? ___

4. Based on your understanding, do the OSHA air and blood lead monitoring requirements apply to this facility? _____

If no, why not?
Use lead only in small quantities ___
Use lead infrequently ___
Exposures to lead are too low ___
Too few employees expopsed to lead ___
Other (specify) ___ ____________________

5. Has this shop ever been inspected by OSHA? ______

If yes, when?______ Results:

6. In what year was this shop built?______________

7. Number of radiator repair stations:______________

8. Number of repair mechanics:______________

9. Number of other employees:

Job Title	Number
____________	___
____________	___
____________	___
____________	___
____________	___
____________	___
____________	___

10. Average number of radiators repaired: (per day) ________
(summer peak) ________

11. Types of radiators repaired: auto_____
truck_____
other_____ specify:

12. Type and amount of solder(s) used:

Type	Amount (e.g. per shift)
____________	_____
____________	_____
____________	_____

13. Type of torch(es) used:____
(eg. Amercian, National, etc)

Also, fuel mixture used: ____
(eg. natural gas-compressed air, propane-air, oxygen-acetylene, etc.)

14. Type of engineering controls:
(inc. installation date)

	Control	Date
(example)	local exhaust hood	2/87
	____________________	_____
	____________________	_____
	____________________	_____
	____________________	_____

Miscellaneous notes:

15. Is health and safety training provided to new employees? _____
Is follow-up training provided (e.g. annual refresher)? _____

Description of training program:

16. Personal protective equipment provided:

	Job	Type
(example)	mechanic	safety glasses, gloves

Specific product information (mfr, model, etc) for all PPE:

Miscellaneous information (including frequency of cleaning, repair, etc):

17. Have air samples for lead ever been collected?______
If yes, complete the following:

	When	Who	Records?
(example)	06/25/89	OSHA	available

How often are air samples for lead collected?
Every ____ months
Periodically, but at no set interval ____
Only at employee request ____
Other:

Miscellaneous information (e.g., type of data included):
(Attach an example of record, if available)

18. Have blood lead levels ever been determined?______
If yes, complete the following:

	When	Who Collected*	Jobs Sampled	Records?
(example)	06/25/89	OSHA	mechanic	available

*Provide name and address of laboratory, if known.

How often are employee blood lead levels checked?
Every ____ months
Periodically, but at no set interval ____
Only at employee request ____
Other:

Miscellaneous information (e.g., type of data included):
(Attach an example of record, if available)

Diagram of the facility:

APPENDIX G Sampling Data Sheet

NIOSH/UC Study of Lead in Radiator Repair Shops
SAMPLING DATA SHEET

Employee Name: ______________________ Shop Name: ______________
Address: ______________________
____
Phone: ( ) ______________________
Job Title: ______________________ Time in job: ______________

Date	Sample #	Pump #	On	Off	Total time	Flow rate	Volume	Notes

Number of radiators soldered during sampling: _______
Amount of time spent tearing down, repairing or recoring radiators:

Other activities during sampling:

Was PPE worn during sampling?_____ If so, fullshift?_______
or, only during certain activities?_______

Describe equipment and wearing:

Did employee use tobacco/gum during sampling?_____ If so, where & how often?

cigarettes____ # cigars____ # chewing tobacco____ # chewing gum____

Did employee eat in the work area?______ If so, did he wash hands prior?_____

Describe personal hygiene practices:

Does employee shower and change clothes before going home?_____
Does employee wear work shoes home?_____
Does employee bite his/her fingernails?_____

Describe other work practices which may affect exposure:

APPENDIX H Environmental Data Sheet

NIOSH/UC Study of Lead in Radiator Repair Shops

ENVIRONMENTAL DATA SHEET

Shop Name:__________________

Date	Time	Location	Dry bulb	Wet bulb	% RH	Air speed	Baro press	Weather conditions	Notes

Comments:

APPENDIX I Letter of Survey Results: Shop 1

January 2, 1992

Cincinnati, Ohio 45251

Dear Mr. :

This letter is to inform you of the results of the NIOSH industrial hygiene survey conducted at your radiator repair shop last July. As you know, air and wipe samples were collected to assess occupational exposures to inorganic lead over a four-day period during typical radiator repair work. The results from this survey are summarized in Tables I-III; a diagram of your facility is enclosed to provide some reference to the sampling locations.

Table I summarizes airborne lead concentrations found in your workplace. Samples were collected and analyzed by graphite furnace atomic absorption spectrophotometry following NIOSH Method 7105.[1] All of the sample results were well below both the Occupational Safety and Health Administration (OSHA) *Permissible Exposure Limit (PEL)* of 50 micrograms of lead per cubic meter of air ($\mu g/m^3$) and the *Action Level (AL)* of 30 $\mu g/m^3$, both expressed as an average over an 8-hour workshift.[2] The highest concentration (19 $\mu g/m^3$) was found for a full-shift sample worn by a radiator mechanic; none of the other 11 personal samples exceeded 10 $\mu g/m^3$. Likewise, all area samples taken in various locations throughout the radiator shop and surrounding areas were quite low. Two short-term samples collected during continuous soldering (7 minutes at test tank #1 and 30 minutes at tank #2) had concentrations of 7.1 and 4.1 $\mu g/m^3$, respectively (not shown in Table I). A possible explanation for some of the difference between these two sample concentrations was the proximity of the flexible ventilation hood to the workstand during soldering, generally observed to be positioned slightly closer at test tank #2.

Table II presents the results of wipe samples collected from workers' hands, foreheads, and personal automobiles. Each worker wiped their own hands for 30 seconds whereas foreheads and automobile interiors were wiped by a NIOSH industrial hygienist; samples were collected on commercially-available, pre-moistened towelettes prior to any washing. Results indicated that workers' skin was highly contaminated by lead, with concentrations as high as 23,000 $\mu g/m^2$ on hands and 6000 $\mu g/m^2$ on the forehead. The highest concentration found inside a worker's car was over 3000 $\mu g/m^2$ on the driver's armrest, indicating that lead contamination was not confined to the work environment.

Table III summarizes the lead concentrations found on various surfaces which persons are likely to contact. Although concentrations were predictably highest in the vicinity of the test tanks where soldering is done, lead contamination was also found in the restroom, shop office, and lunchroom.

Lead contamination was thus shown to be pervasive throughout the facility, and therefore potentially exposing other workers and even customers to lead through skin contact and possibly resulting in their ingestion of lead. Considering the low airborne lead levels, surface contamination is most probably a result of an accumulation of lead dust over prolonged periods, largely due to poor housekeeping.

Presently, there are no Federal criteria for surface contamination in occupational environments but the U.S. Department of Housing and Urban Development (HUD) recommends surface contamination be less than 200 $\mu g/ft^2$ (about 2160 $\mu g/m^2$) on the floors and less than 500 $\mu g/m^2$ (5400 $\mu g/m^2$) on window sills in residential housing following removal of lead-based paint.[3] These guidelines were primarily established with the goal of preventing lead poisoning in housing occupants, particularly young children. In the residential environment, the length of exposure, the potential for contact with surface contamination, and the frequency of hand-to-mouth contact is generally considered to be much greater than in the occupational environment. Therefore, direct comparison between our results and the HUD level may not be applicable but should provide some reference for assessing the degree of lead contamination.

Based on the results of the survey at your radiator shop, the following comments and recommendations are made:

1. The local exhaust ventilation system used in this shop was found to effectively control lead exposures during radiator repair activity. In general, the effectiveness of the flexible duct exhaust system is dependent on the positioning of the hood near the source of lead fumes. Workers should be encouraged to frequently move the hood, whenever necessary, to ensure the most efficient capture of lead fumes. Because of the low airborne lead exposures in this shop, respirators are not required and were not used.

2. Considering the high potential for surface contamination by lead, smoking and eating in work areas, although observed during our survey, should not be allowed. Incidently, considering the proximity to the test tanks and the measured contamination in the area, the shop office should also be considered a work area

in which smoking and eating are not permitted. Daily clean-up of frequently contacted surfaces, especially desktops, telephones, restrooms, and lunchrooms, is highly encouraged. Cleanup should only be done using HEPA filter vacuum or wet wash (eg. high-phosphate detergent solution) methods. Finally, workers should be frequently reminded (e.g., by posting signs) to thoroughly clean their hands and face before eating, drinking, or smoking.

3. Workers should be required to use the professionally-laundered work uniforms (both pants and shirt) provided daily by the employer. Workers should remove and leave dirty uniforms and workshoes and thoroughly clean their hands, arms, and face (showering is preferable) **before** leaving the worksite to prevent possible contamination of cars, homes, and families.

4. You are reminded that it is the **employer's** responsibility to conduct the initial determination of air concentrations in any workplace using lead. It is the air lead levels which determine whether additional provisions of the OSHA Lead Standard (such as periodic blood testing, warning signs, engineering controls, respirator program, and medical removal) are required.[2] Although you had not conducted any previous air sampling, the lead concentrations measured during this survey were all below the OSHA Action Level of 30 $\mu g/m^3$. Per a conversation with the local OSHA office, the results of this NIOSH survey can be used to satisfy the "initial determination" monitoring requirement.[4]

Therefore based on these results, your shop appears to be in general compliance and exempt from all most provisions of the Lead Standard except those specified in Appendices A and B to 29 CFR Section 1910.1025 which requires that employees be **informed** of the hazards of lead use and of the key provisions of the Lead Standard. You are strongly encouraged to thoroughly review the OSHA Lead Standard (a copy of which was given to you during our survey) to ensure your compliance with the legal requirements as an employer.

In summary, the sampling data from the NIOSH survey at your workplace indicate that exposures to airborne lead are typically well below occupational exposure criteria. However, high levels of surface contamination were found throughout the worksite and conscientious efforts should be directed to regular cleaning of surfaces and skin to minimize the potential for lead ingestion. Work clothing should not be taken home to prevent secondary lead exposures to workers' families.

I have enclosed several articles and pamphlets which provide guidance for safely working with lead. In particular, the two NIOSH publications concerning lead in the construction industry contain very pertinent and useful information for controlling lead exposures in <u>any</u> industry where lead is used. Also, I recommend that you post this letter and keep the articles in a general location readily seen by employees for their information.

If you have any questions or require further details on this survey, please call me at (513) 841-4314. If any corrections to this letter are requested, please notify me in writing by January 31, 1991. I'd like to thank you again for your participation and continued interest in this study; the cooperation and assistance of you and your employees is sincerely appreciated.

Sincerely yours,

Greg M. Piacitelli, CIH
Supervisory Industrial Hygienist
Industrial Hygiene Section
Industrywide Studies Branch
Division of Surveillance, Hazard
Evaluations, and Field Studies

8 Enclosures

GMPIACITELLI:klf:RmB22:Hamilton:CintiOH:

Table I
SUMMARY OF FULL-SHIFT AIRBORNE LEAD SAMPLING RESULTS
Radiator Shop
Cincinnati, Ohio
July 7-11, 1991

JOB/AREA	AVERAGE TWA ($\mu g/m^3$)	N	RANGE
Personal Samples			
Radiator mechanic (ME)	7.5	4	2.8-19.
Radiator mechanic (RJ)	6.2	4	4.6-8.1
Radiator mechanic (GW)	5.9	4	3.3-7.8
ALL	6.5	12	2.8-19.
Area Samples			
Test tank #1 (ME work station)	3.3	3	2.0-4.4
Test tank #2 (RJ work station)	2.1	2	2.0-2.2
Work bench (GW work station)	2.2	4	1.3-4.5
Radiator shop office	2.9	3	1.3-5.7
Tool stand between test tanks #1 & #2	1.7	2	1.5-1.8
General area of shop (15' from test tanks)	.77	3	.46-1.2
Main office	.18	3	.10-.34
Lunchroom	.14	3	.08-.22
Background (outdoors)	<.05	3	<.05-<.06
OSHA PERMISSIBLE EXPOSURE LIMIT (PEL) **OSHA ACTION LIMIT**	50 30		

TWA = time-weighted average (in micrograms lead per cubic meter air).
N = number of samples

Table II
SUMMARY OF PERSONAL WIPE SAMPLING RESULTS
Radiator Shop
Cincinnati, Ohio
July 7-11, 1991

JOB	HANDS[a]		FOREHEAD[b]	AUTO/TRUCK (armrest)
	Prelunch	Postshift	Postshift	
	Average Lead Concentration ($\mu g/m^2$)			
Radiator mechanic (ME)	8329 n=3	6628 n=4	6720 n=4	3066 n=1
Radiator mechanic (RJ)	19866 n=3	23609 n=4	4000 n=4	1300 n=1
Radiator mechanic (GW)	11207 n=3	9555 n=4	5680 n=4	976 n=1
ALL	13134 n=9	13265 n=12	5440 n=12	1781 n=3

[a]Area = 820 cm^2 based on EPA criteria.
[b]Area = 25 cm^2 measured.

HUD clearance criteria (residential housing)[3]:

floors: 200 $\mu g/ft^2$ (2160 $\mu g/m^2$)
window sills: 500 $\mu g/ft^2$ (5400 $\mu g/m^2$)
window wells: 800 $\mu g/ft^2$ (8640 $\mu g/m^2$)
Note: 1 $\mu g/ft^2$ = 10.8 $\mu g/m^2$

Table III
SUMMARY OF AREA WIPE SAMPLING RESULTS
Radiator Shop
Cincinnati, Ohio
July 7-11, 1991

AREA	SURFACE AREA WIPED (cm^2)	LEAD CONCENTRATION ($\mu g/m^2$)
Test tank #1 (outer edge)	500	500,000
Test tank #1 LEV flanged hood (inside)	100	4,100,000
Test tank #2 impact wrench handle	100	15,600
Mechanic's used work glove (inside palm)	50	29,200
Forklift steering wheel	200	5,300
Shop telephone handle	80	17,000
Shop office: desk top	225	1,066
Shop office: door knob	78	14,777
Shop office: telephone handle	80	84,500
Lunchroom tabletop	625	96
Restroom urinal handle	18	13,297

HUD clearance criteria (residential housing)[?]:

floors: 200 $\mu g/ft^2$ (2160 $\mu g/m^2$)
window sills: 500 $\mu g/ft^2$ (5400 $\mu g/m^2$)
window wells: 800 $\mu g/ft^2$ (8640 $\mu g/m^2$)
Note: 1 $\mu g/ft^2$ = 10.8 $\mu g/m^2$

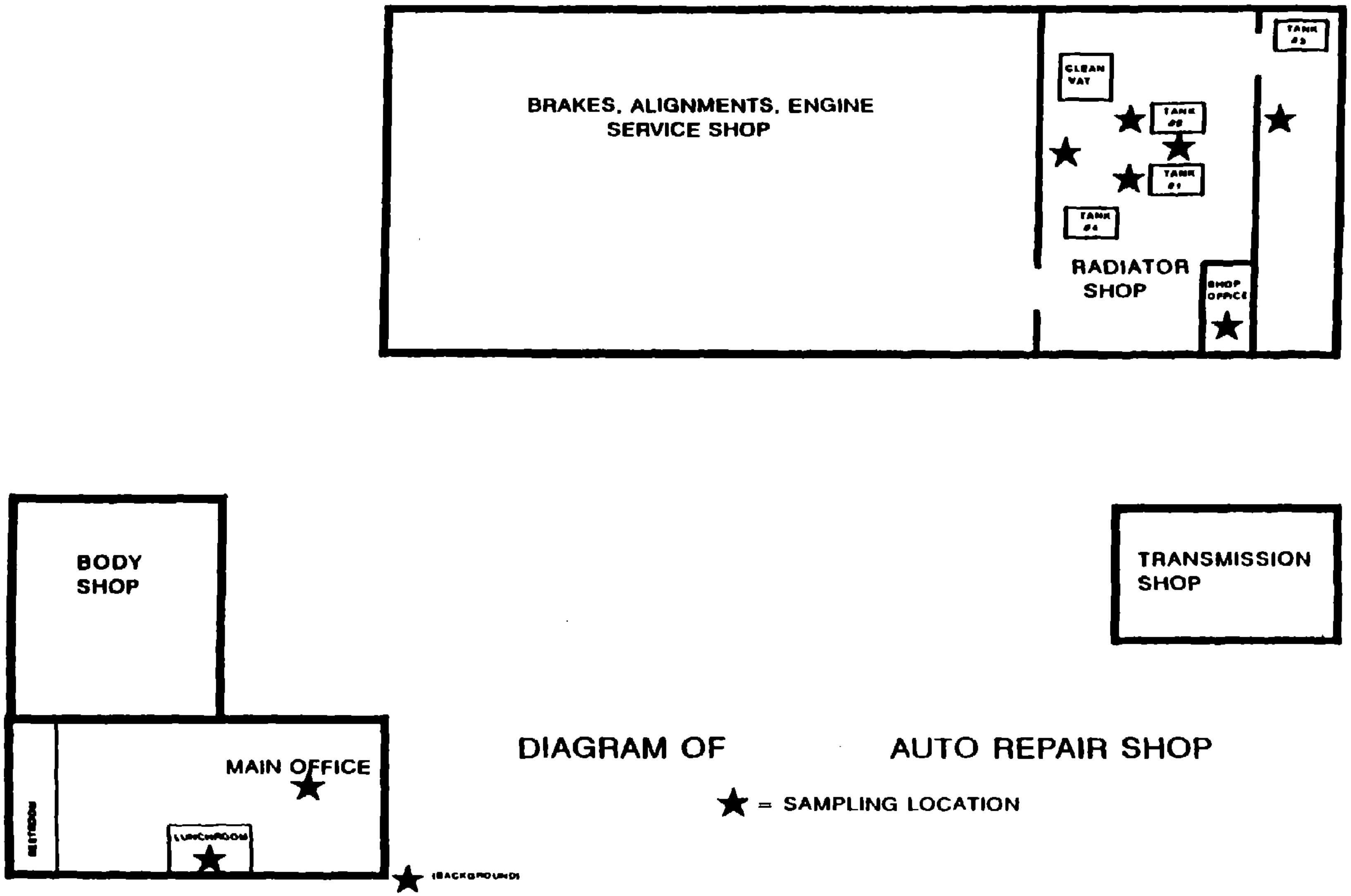


DIAGRAM OF AUTO REPAIR SHOP

★ = SAMPLING LOCATION

References

1. US Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. 1987. Manual of Analytical Methods, Third Edition. Cincinnati, OH.

2. US Department of Labor, Occupational Safety and Health Administration. 1978. Occupational Exposure to Lead--Final Standard. CFR 43:54353-54616.

3. US Department of Housing and Urban Development, Office of Public and Indian Housing. 1990. Lead-Based Paint: Interim Guidelines for Hazard Identification and Abatement in Public and Indian Housing. HUD-005646.

4. Telephone Conversation with Dick Gilchrist, Compliance Officer, Occupational Safety and Health Administration, Cincinnati Office (513) 841-4312, on December 20, 1991.

APPENDIX J Letter of Survey Results: Shop 2

January 15, 1992

Cincinnati, Ohio 45225

Dear Mr. :

This letter is to inform you of the results of the NIOSH industrial hygiene survey conducted at your radiator repair shop last August. As you know, air and wipe samples were collected to assess occupational exposures to inorganic lead over a four-day period during typical radiator repair work. The results from this survey are summarized in Tables I-IV.

Table I summarizes full-shift airborne lead concentrations found in your workplace. Samples were collected and analyzed by graphite furnace atomic absorption spectrophotometry following NIOSH Method 7105.[1] All of the sample results were well below both the Occupational Safety and Health Administration (OSHA) *Permissible Exposure Limit (PEL)* of 50 micrograms of lead per cubic meter of air ($\mu g/m^3$) and the *Action Level (AL)* of 30 $\mu g/m^3$, both expressed as an average over an 8-hour workshift.[2] The highest concentration (7.1 $\mu g/m^3$) was found for a full-shift sample worn by a radiator mechanic; none of the other 11 personal samples exceeded 6.0 $\mu g/m^3$. Likewise, all area samples taken in various locations throughout the radiator shop and surrounding areas were quite low, with none exceeding 2.0 $\mu g/m^3$.

Table II presents the individual results of short-term samples taken from one radiator mechanic (DR) over the last three days of the survey. The daily full-shift time-weighted average concentration calculated from these samples is also shown. The amounts of lead on those samples collected only when the mechanic soldered were all below the limit of detection, suggesting that "peak" exposures to lead were quite low. Therefore, while it was difficult to determine the actual lead exposure during soldering alone, results are consistent with the long-term samples which indicated that exposures to airborne lead were very low in your workplace.

Table III presents the results of wipe samples collected from workers' hands, foreheads, and personal vehicles. Each worker wiped their own hands for 30 seconds whereas foreheads and automobile interiors were wiped by a NIOSH industrial hygienist; samples were collected on commercially-available, pre-moistened towelettes prior to any washing. Sampling indicated that workers' skin was highly contaminated by lead at the end of the workshift, with concentrations as high as 12,000 $\mu g/m^2$ on hands and almost 5000 $\mu g/m^2$ on the forehead. Workers were then instructed to wash their hands, in their usual manner, and wipe samples were again taken. These results demonstrate that, although washing removed the majority of the lead from workers' hands, a substantial amount of lead remained on worker's prior to leaving the workplace. Further, lead concentrations over 19,000 $\mu g/m^2$ were found on the driver's armrest in personal vehicles, indicating that lead contamination was not confined to the work environment.

Table IV summarizes the lead concentrations found on various surfaces which persons are likely to contact. Most notable were the samples indicating high levels of lead contamination in the restroom, office/lunchroom, workers' shoes, and personal vehicles. Lead contamination was thus shown to be pervasive throughout the facility, therefore potentially exposing all workers and even customers to lead through skin contact and possibly resulting in their ingestion of lead. Considering the low airborne lead levels, surface contamination is most probably a result of an accumulation of lead dust over prolonged periods largely due to poor housekeeping and/or to poor work practices.

Presently, there are no Federal criteria for surface contamination in occupational environments but the U.S. Department of Housing and Urban Development (HUD) recommends surface contamination be less than 200 $\mu g/ft^2$ (about 2160 $\mu g/m^2$) on the floors and less than 500 $\mu g/ft^2$ (5400 $\mu g/m^2$) on window sills in residential housing following removal of lead-based paint.[3] These guidelines were primarily established with the goal of preventing lead poisoning in housing occupants, particularly young children. In the residential environment, the length of exposure, the potential for contact with surface contamination, and the frequency of hand-to-mouth contact is generally considered to be much greater than in the occupational environment. Therefore, direct comparison between our results and the HUD level may not be applicable but should provide some reference for assessing the degree of lead contamination.

Based on the results of the survey at your radiator shop, the following comments and recommendations are made:

1. The local exhaust ventilation systems used in this shop were found to effectively control lead exposures during radiator repair activity. In general, the effectiveness of the flexible duct exhaust system is dependent on the positioning of the hood near the source of lead fumes. Workers should be encouraged to frequently move the hood, whenever necessary, to ensure the most efficient capture of lead fumes. Because of the low airborne lead exposures in this shop, respirators are not required and were not used.

2. Considering the high potential for surface contamination by lead, smoking and eating in work areas, although observed during our survey, should not be allowed.

Incidently, considering the proximity to the test tanks and the measured contamination in the area, the shop office should also be considered a work area in which smoking and eating are not permitted. Daily clean-up of frequently contacted surfaces, especially desk tops, telephones, restrooms, and lunchrooms, is highly encouraged. Cleanup should only be done using HEPA filter vacuum or wet wash (eg. high-phosphate detergent solution) methods. Finally, workers should be frequently reminded (e.g., by posting signs) to thoroughly clean their hands and face before eating, drinking, or smoking.

3. Workers should be required to use the professionally-laundered work uniforms (both pants and shirt) provided daily by the employer. Workers should remove and leave dirty uniforms and workshoes and thoroughly clean their hands, arms, and face (showering is preferable) **before** leaving the worksite to prevent possible contamination of cars, homes, and families.

4. You are reminded that it is the **employer's** responsibility to conduct the initial determination of air concentrations in any workplace using lead. It is the air lead levels which determine whether additional provisions of the OSHA Lead Standard (such as periodic blood testing, warning signs, engineering controls, respirator program, and medical removal) are required.[2] Although you had not conducted any previous air sampling, the lead concentrations measured during this survey were all below the OSHA Action Level of 30 $\mu g/m^3$. Per a conversation with the local OSHA office, the results of this NIOSH survey can be used to satisfy the "initial determination" monitoring requirement.[4] Therefore, based on these results, your shop appears to be in general compliance and exempt from all provisions of the Lead Standard except those specified in Appendices A and B to 29 CFR Section 1910.1025 which requires that employees be **informed** of the hazards of lead use and of the key provisions of the Lead Standard. You are strongly encouraged to thoroughly review the OSHA Lead Standard (a copy of which was given to you during our survey) to ensure your compliance with the legal requirements as an employer.

In summary, the sampling data from the NIOSH survey at your workplace indicate that exposures to airborne lead are typically well below occupational exposure criteria. However, high levels of surface contamination were found throughout the worksite and conscientious efforts should be directed to regular cleaning of surfaces and skin to minimize the potential for lead ingestion. Work clothing should not be taken home to prevent secondary lead exposures to workers' families.

I have enclosed several articles and pamphlets which provide guidance for safely working with lead. In particular, the two NIOSH publications concerning lead in the construction industry contain very pertinent and useful information for controlling lead exposures in any industry where lead is used. Also, I recommend that you post this letter and keep the articles in a general location readily seen by employees for their information.

If you have any questions or require further details on this survey, please call me at (513) 841-4314. If any corrections to this letter are requested, please notify me in writing by January 31, 1992. I'd like to thank you again for your participation and continued interest in this study; the cooperation and assistance of you and your employees is sincerely appreciated.

Sincerely yours,

Greg M. Piacitelli, CIH

8 Enclosures

Table I
SUMMARY OF FULL-SHIFT AIRBORNE LEAD SAMPLING RESULTS
Radiator Shop
Cincinnati, Ohio
July 29-August 1, 1991

JOB/AREA	AVERAGE TWA (μg/m³)	N	RANGE
Personal Samples			
Radiator mechanic (DR)	3.0	4	1.2-4.9
Radiator mechanic (RR)	1.6	4	1.0-2.1
Radiator mechanic (GR)	4.9	3	1.7-7.1
ALL	3.0	11	1.0-7.1
Area Samples			
Test tank #1 (DR work station)	0.9	4	0.1-1.3
Test tank #2 (RR & GR work station)	0.8	3	0.5-1.2
Soldering booth (GR work station)	1.3	3	0.5-2.0
Shop (15' from tanks; next to bay door)	0.4	4	<.24-.71
Shop office/lunch area	1.2	4	0.9-1.5
Parking (5' below LEV discharge)	.11	4	.05-.17
Background (outdoors)	<.05	4	<.05-<.05
OSHA PERMISSIBLE EXPOSURE LIMIT (PEL)	50		
OSHA ACTION LIMIT	30		

TWA = time-weighted average (in micrograms lead per cubic meter air).
N = number of samples

Table II
SUMMARY OF SHORT-TERM AIRBORNE LEAD SAMPLING RESULTS
Radiator Shop
Cincinnati, Ohio
July 29-August 1, 1991

DATE	JOB	SAMPLE DURATION (minutes)	SOLDERING DURATION (minutes)	LEAD CONCENTRATION ($\mu g/m^3$)
7/30/91	Rad mechanic (DR)	101	6	5.2
		52	2	1.0
		8	8	<3.1
		7	7	<3.6
		205	0	1.6
		19	5	1.9
		91	9	4.3
		45	0	2.3
	Time-weighted average	528	37	2.7
7/31/91	Rad mechanic (DR)	55	8	2.5
		158	25	1.7
		63	10	<.41
		113	0	1.4
		72	0	<.36
	Time-weighted average	461	43	1.2
8/1/91	Rad mechanic (DR)	195	5	3.4
		6	6	<4.2
		189	0	1.3
		119	3	6.0
	Time-weighted average	509	14	3.2
OSHA PERMISSIBLE EXPOSURE LIMIT (PEL)				50
OSHA ACTION LIMIT (AL)				30

Table III
SUMMARY OF PERSONAL WIPE SAMPLING RESULTS
Radiator Shop
Cincinnati, Ohio
July 29-August 1, 1991

JOB	HANDS[a] Postshift		FOREHEAD[b]	AUTO/TRUCK (armrest)
	Pre-Wash	Post-Wash	Postshift	
	Average Lead Concentration ($\mu g/m^2$)			
Radiator mechanic (DR)	6,890 n=4	841 n=4	2,666 n=3	19,000 n=1
Radiator mechanic (RR)	9,207 n=4	293 n=4	1,013 n=3	9,200 n=1
Radiator mechanic (GR)	10,163 n=3	460 n=3	4,940 n=2	no samples
Shop helper (SC)	12,409 n=4	516 n=3	no samples	no samples
ALL	9,634 n=15	533 n=14	2,615 n=8	14,100 n=2

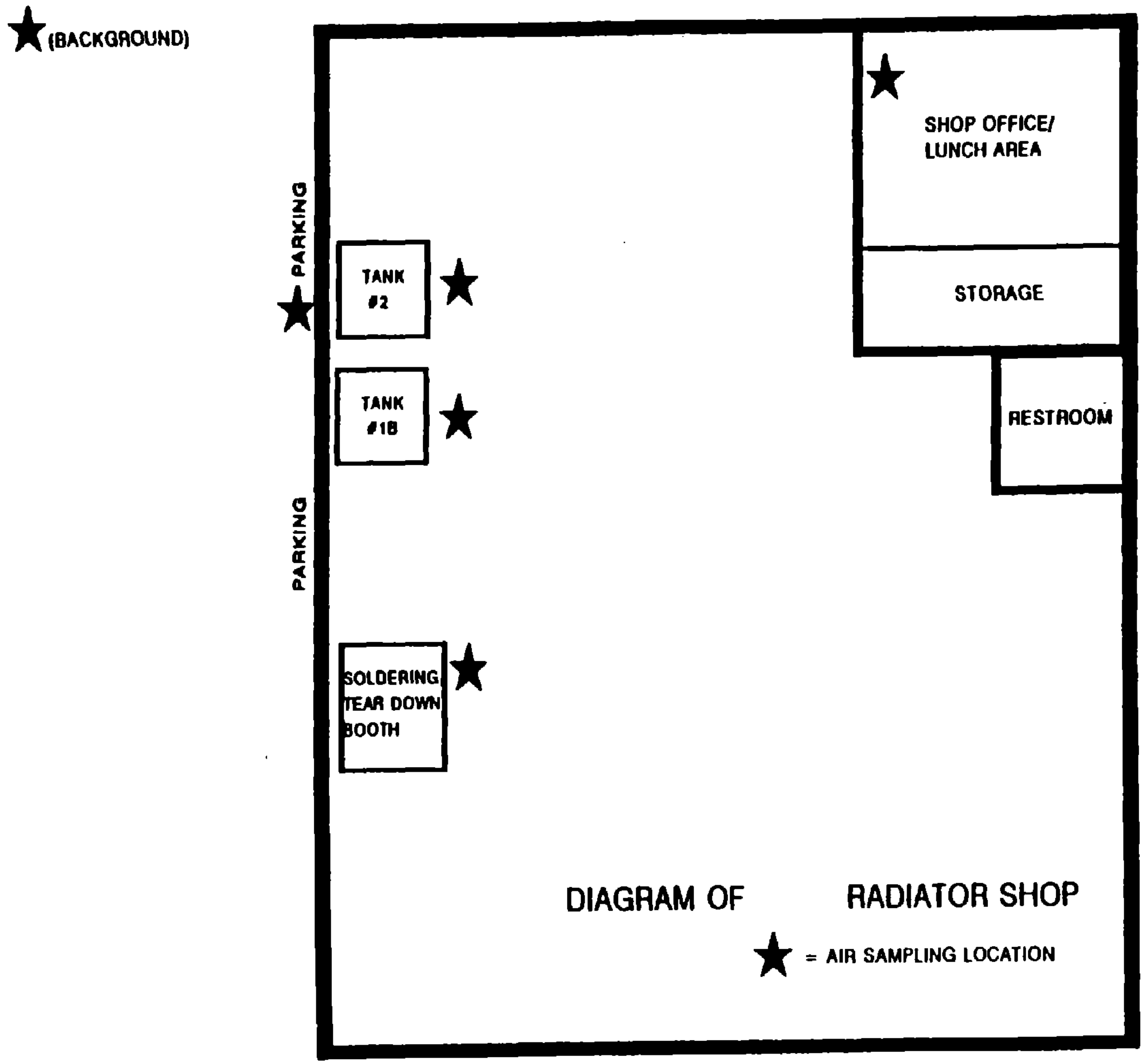
[a]Area = 820 cm^2 based on EPA criteria.[5]
[b]Area = 25 cm^2 measured.

HUD clearance criteria (residential housing)[3]:
floors: 200 $\mu g/ft^2$ = (2160 $\mu g/m^2$)
window sills: 500 $\mu g/ft^2$ = (5400 $\mu g/m^2$)
window wells: 800 $\mu g/ft^2$ = (8640 $\mu g/m^2$)
Note: 1 $\mu g/ft^2$ = (10.8 $\mu g/m^2$)

Table IV
SUMMARY OF AREA WIPE SAMPLING RESULTS
Radiator Shop
Cincinnati, Ohio
July 29-August 1, 1991

AREA	SURFACE AREA WIPED (cm^2)	LEAD CONCENTRATION ($\mu g/m^2$)
Shop phone (receiver)	80	18,750
Shop bathroom lightswitch plate	77	18,182
Shop bathroom toilet flush handle	18	5,555
Office phone (receiver)	80	3,875
Shop truck: steering wheel	200	20,500
: driver's seat	100	1,400
Top of streetshoe (DR)	50	20,000
Top of streetshoe (RR)	50	46,000
Personal vehicle (RR): driver's seat	80	84,500
(Note: Vehicle : arm rest	100	9,200
also used for : driver's floormat	100	9,600
shop business) : passenger's seat	100	2,100
: gas pedal	50	19,600
Personal vehicle (DR): arm rest	100	19,000
: driver's floormat	100	68,000
: gas pedal	50	68,000
: dashboard	100	21,000

HUD clearance criteria (residential housing)[3]:
floors: 200 $\mu g/ft^2$ = (2160 $\mu g/m^2$)
window sills: 500 $\mu g/ft^2$ = (5400 $\mu g/m^2$)
window wells: 800 $\mu g/ft^2$ = (8640 $\mu g/m^2$)
Note: 1 $\mu g/ft^2$ = (10.8 $\mu g/m^2$)


(BACKGROUND)
PARKING
PARKING
TANK #2
TANK #1B
SOLDERING TEAR DOWN BOOTH
SHOP OFFICE/ LUNCH AREA
STORAGE
RESTROOM
DIAGRAM OF RADIATOR SHOP
= AIR SAMPLING LOCATION

References

1. US Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. 1987. Manual of Analytical Methods, Third Edition. Cincinnati, OH.

2. US Department of Labor, Occupational Safety and Health Administration. 1978. Occupational Exposure to Lead--Final Standard. CFR 43:54353-54616.

3. US Department of Housing and Urban Development, Office of Public and Indian Housing. 1990. Lead-Based Paint: Interim Guidelines for Hazard Identification and Abatement in Public and Indian Housing. HUD-005646.

4. Telephone Conversation with Dick Gilchrist, Compliance Officer, Occupational Safety and Health Administration, Cincinnati Office (513) 841-4312, on December 20, 1991.

5. US Environmental Protection Agency, 1986. Pesticide Assessment Guidelines, Subdivision U: Applicator Exposure Monitoring. NTIS PB87-133286.

APPENDIX K Letter of Survey Results: Shop 3

January 24, 1992

Cincinnati, Ohio 45102

Dear Mr. :

This letter is to inform you of the results of the NIOSH industrial hygiene survey conducted at your radiator repair shop last August. As you know, air and wipe samples were collected to assess occupational exposures to inorganic lead over a four-day period during typical radiator repair work. The results from this survey are summarized in Tables I-III; a diagram of your facility is also attached to provide some reference as to the sampling locations.

Table I summarizes personal airborne lead concentrations found in your workplace. Samples were collected and analyzed by graphite furnace atomic absorption spectrophotometry following NIOSH Method 7105.[1] Several of the sample results were well **above** both the Occupational Safety and Health Administration (OSHA) *Action Level (AL)* of 30 micrograms of lead per cubic meter of air ($\mu g/m^3$) and the *Permissible Exposure Limit (PEL)* of $50 \mu g/m^3$, both expressed as an average over an 8-hour workshift.[2] Many of the samples with high lead concentrations are of short sampling duration and are not appropriate for direct comparison to the OSHA criteria. Therefore, the daily 8-hour time-weighted average (TWA_8) exposure is calculated for each worker, assuming zero exposure to lead during any unsampled work period. As shown in Table I, two of the five TWA_8 exposures exceeded the OSHA PEL, another exceeded the AL. The highest TWA_8 exposure was 157 $\mu g/m^3$ or more than three times the level OSHA considers acceptable. Also of immediate concern are the very high "peak" concentrations of lead measured over shorter sampling durations (up to 810 $\mu g/m^3$ over a one-hour period). These short-term samples were generally collected between the time a mechanic started and stopped work on an individual radiator, indicating that tear down and/or soldering resulted in very high exposures to lead. These data also indicate that excessive full-shift exposures to lead resulted despite the observation that only relatively little time was actually spent repairing radiators.

Full-shift area sampling results are presented in Table II. The highest concentration measured was 180 $\mu g/m^3$ immediately adjacent to the repair tank (Tank #1 in the diagram) most frequently used during the survey period. These sampling data indicate that the high airborne lead concentrations at your facility are generally confined to the radiator repair room: none of the samples collected outside of the repair room exceeded 2.0 $\mu g/m^3$.

Table III presents the results of wipe samples collected from workers' hands and from various surfaces which persons are likely to contact. Each worker wiped their own hands for 30 seconds (prior to any washing) whereas surfaces were wiped by a NIOSH industrial hygienist: all samples were collected on commercially-available, pre-moistened towelettes. Sampling indicated that workers' hands were highly contaminated by lead at the end of the workshift, with average concentrations as high as 39,000 $\mu g/m^2$. Of the area samples, high levels of lead contamination were found in the radiator repair room and on a phone in close vicinity to that room. Though considerably lower, lead contamination was also found in the office, men's restroom, and customer waiting/employee break area. Lead contamination was thus shown to be pervasive throughout the facility, therefore potentially exposing all workers and even customers to lead through skin contact and possibly resulting in their ingestion of lead. Considering the low airborne lead levels in some of these areas, surface contamination is probably a result of an accumulation of lead dust over prolonged periods largely due to poor housekeeping and/or to poor work practices. In addition, the settling of lead aerosol most likely contributes to the lead found on surfaces in the radiator repair room.

Presently, there are no Federal criteria for surface contamination in occupational environments but the U.S. Department of Housing and Urban Development (HUD) recommends surface contamination be less than 200 $\mu g/ft^2$ (about 2160 $\mu g/m^2$) on the floors and less than 500 $\mu g/ft^2$ (5400 $\mu g/m^2$) on window sills in residential housing following removal of lead-based paint.[3] These guidelines were primarily established with the goal of preventing lead poisoning in housing occupants, particularly young children. In the residential environment, the length of exposure, the potential for contact with surface contamination, and the frequency of hand-to-mouth contact is generally considered to be much greater than in the occupational environment. Therefore, direct comparison between our results and the HUD level may not be applicable but should provide some reference for assessing the degree of lead contamination.

Based on the results of the survey at your radiator shop, the following comments and recommendations are made:

1. You are reminded that it is the **employer's** responsibility to conduct the initial determination of air concentrations in any workplace using lead. It is the air lead levels which determine whether additional provisions of the OSHA Lead Standard (such as periodic blood testing, warning signs, engineering controls, respirator program, and medical removal) are required.[2] Per a conversation with the local

OSHA office, the results of this NIOSH survey can be used to satisfy the "initial determination" monitoring requirement.[4] Therefore, based on these results, your shop appears to be in **non-compliance** with many provisions of the Lead Standard, including those specified in Appendices A and B to 29 CFR Section 1910.1025 which requires that employees be informed of the hazards of lead use and of the key provisions of the Lead Standard.

2. Because worker exposures to lead exceeded the *Permissible Exposure Limit* of 50 $\mu g/m^3$, OSHA requires the employer to (a) reduce lead exposures to below the PEL by installing engineering controls, such as an **effective** ventilation system; (b) provide employees with respirators (an air-purifying type approved for use with lead dust and fumes) and require use until exposures are reduced below the PEL; (c) provide clean work clothing, showers, and separate lunch room; (d) provide blood testing of exposed employees; (e) repeat air sampling within 3 months and provide workers with written results; and (f) provide worker training on lead safety.

3. Blood-lead testing is required for all employees working in any areas exceeding the *Action Level* (30 $\mu g/m^3$). Blood-testing has the advantage over air sampling for assessing exposures to lead since it detects lead poisoning caused by breathing lead aerosol **and/or** by ingesting lead particulate. Initial blood-tests are typically less than $50 per worker and readily available from most medical providers. The frequency of subsequent blood-testing and any medical removal provisions are determined by an individual's blood-lead levels. Based on the results of our survey, you are strongly advised to arrange blood-testing of your radiator mechanics **immediately**. Please forward the results of these tests to me when avaialable.

4. OSHA requires that air sampling be repeated every three months if air lead levels are above the PEL, or every six months if below the PEL but above the AL. Sampling must be repeated at these frequencies until at least two consecutive samples, taken at least seven days apart, are below the AL, at which time the employer may discontinue air monitoring, unless a process or personnel change occurs which may result in new or additional exposure to lead.

5. The ventilation system (a propeller fan in a remote wall and two ceiling fans) used in this shop was found to be ineffective for controlling lead exposures during radiator repair activity. I recommend that you contact a professional firm specializing in industrial ventilation systems for installing and monitoring the proper operation of either an "elephant trunk" or a "back-draft booth" system, specifically designed to control lead exposures in a radiator repair shop. An article describing a cost-effective ventilation system is included with this letter.

6. Considering the high potential for surface contamination by lead, smoking and eating in work areas, although observed during our survey, should not be allowed. Daily clean-up of frequently contacted surfaces, especially desktops, telephones, restrooms, and lunchrooms, is highly encouraged. Cleanup should only be done using HEPA filter vacuum or wet wash (eg. high-phosphate detergent solution) methods. Finally, workers should be frequently reminded (e.g., verbally and by posting signs) to thoroughly clean their hands and face before eating, drinking, or smoking.

7. Workers should be required to use the professionally-laundered work uniforms (both pants and shirt) provided daily by the employer. Workers should remove and leave dirty uniforms and workshoes and thoroughly clean their hands, arms, and face (showering is preferable) **before** leaving the worksite to prevent possible contamination of cars, homes, and families.

In summary, the sampling data from the NIOSH survey at your workplace indicate that exposures to airborne lead are well above occupational exposure criteria. Immediate action should be taken to conduct blood-testing of all radiator mechanics, to install a new ventilation system to reduce airborne lead levels, and to require respirators be worn until exposures are below the PEL. In addition, surface contamination was found throughout the worksite and conscientious efforts should be directed to regular cleaning of surfaces and skin to minimize the potential for lead ingestion. To prevent secondary lead exposures to workers' families, work clothing should not be taken home.

The requirements of the OSHA Lead Standard are quite specific and detailed. You are strongly advised to thoroughly review its key provisions (a copy of the Lead Standard and a Lead Training manual were given to you during our survey) and to consult with the local OSHA office (phone: 513 841-4312), if necessary, to ensure your compliance with the legal requirements as an employer. The state of Ohio's OSHA-supported free consultation program (phone: 614 644-2631) is also available to provide technical assistance, particularly to high hazard small businesses.

I have enclosed several articles and pamphlets which provide some guidance for safely working with lead. In particular, the two NIOSH publications concerning lead in the construction industry contain very pertinent and useful information for controlling lead exposures in any industry where lead is used. Also, I request that you post this letter and keep the articles in a general location readily seen by employees for their information.

If you have any questions or require further details on this survey, please call me at (513) 841-4314. If any corrections to this letter are requested, please notify me in writing by February 15, 1992.

I'd like to thank you again for your participation and continued interest in this study; the cooperation and assistance of you and your employees is sincerely appreciated.

Sincerely yours,

Greg M. Piacitelli, CIH
Supervisory Industrial Hygienist
Industrial Hygiene Section
Industrywide Studies Branch
Division of Surveillance, Hazard
Evaluations, and Field Studies

8 Enclosures

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Table I
SUMMARY OF PERSONAL AIRBORNE LEAD SAMPLING RESULTS
Radiator Shop
Cincinnati, Ohio
August 19-21, 1991

DATE	JOB	SAMPLE DURATION (minutes)	RADIATORS REPAIRED (number)	LEAD CONCENTRATION (μg/m³)
8/19/91	Rad mechanic (DP)	42	1	433.
		404	0	3.42
	$TWA_{sampling}$	446	1	43.9
	TWA_{8-hour}	480	1	40.8
8/21/91	Rad mechanic (DP)	56	1	810.
		19	2	261.
		116	1	208.
		54	0	13.5
	$TWA_{sampling}$	245	4	307.
	TWA_{8-hour}	480	4	157.
8/19/91	Rad mechanic (CC)	34	1	352.
	$TWA_{sampling}$	34	1	352.
	TWA_{8-hour}	480	1	24.9
8/20/91	Rad mechanic (CC)	42	1	94.5
		325	0	1.0
	$TWA_{sampling}$	367	1	11.7
	TWA_{8-hour}	480	1	9.0
8/21/91	Rad mechanic (CC)	15	2	104.
		62	0	<0.48
		118	1	309.
		53	1	122.
	$TWA_{sampling}$	248	4	180.
	TWA_{8-hour}	480	4	92.7
OSHA PERMISSIBLE EXPOSURE LIMIT (PEL)				50.
OSHA ACTION LIMIT (AL)				30.

$TWA_{sampling}$ = time-weighted average over the sampled work period
TWA_{8-hour} = time-weighted average over the 8-hour shift (assumes zero lead exposure during unsampled work period)

Table II
SUMMARY OF AREA FULL-SHIFT AIRBORNE LEAD SAMPLING RESULTS
Radiator Shop
Cincinnati, Ohio
August 19-21, 1991

JOB/AREA	AVERAGE TWA ($\mu g/m^3$)	N	RANGE
Radiator repair tank #1	144.	3	119. - 180.
Radiator repair room (15' from tanks)	39.0	3	17. - 96.
Main shop (next to lift)	1.00	3	0.6 - 1.8
Shop office (on desktop)	0.8	3	0.8 - 0.7
Customer waiting area/lunch room	0.7	3	0.6 - 0.9
Background (outdoors)	<.06	3	<.06- <.07
OSHA PERMISSIBLE EXPOSURE LIMIT (PEL) **OSHA ACTION LIMIT**	50. 30.		

TWA = time-weighted average (in micrograms lead per cubic meter air).
N = number of samples

Table III
SUMMARY OF WIPE SAMPLING RESULTS
Radiator Shop
Cincinnati, Ohio
August 19-21, 1991

LOCATION	SURFACE AREA WIPED (cm^2)	LEAD CONCENTRATION ($\mu g/m^2$)
AREA (n=1 at each location)		
Waiting/lunch area (tabletop)	50	882
Shop bathroom (Men's room; faucet knob)	50	722
Office (desktop)	75	948
Phone next to radiator repair (receiver)	80	7,625
Radiator repair room (door knob)	78	50,633
PERSONAL (n=2 at each location)		
Rad mechanic (DP): hands (postshift)	820[a]	39,813
Rad mechanic (CC): hands (postshift)	820[a]	26,886

[a]Area = 820 cm^2 for both hands[5]

HUD clearance criteria (residential housing)[3]
floors: 200 $\mu g/ft^2$ = (2160 $\mu g/m^2$)
window sills: 500 $\mu g/ft^2$ = (5400 $\mu g/m^2$)
window wells: 800 $\mu g/ft^2$ = (8640 $\mu g/m^2$)
Note: 1 $\mu g/ft^2$ = (10.8 $\mu g/m^2$)

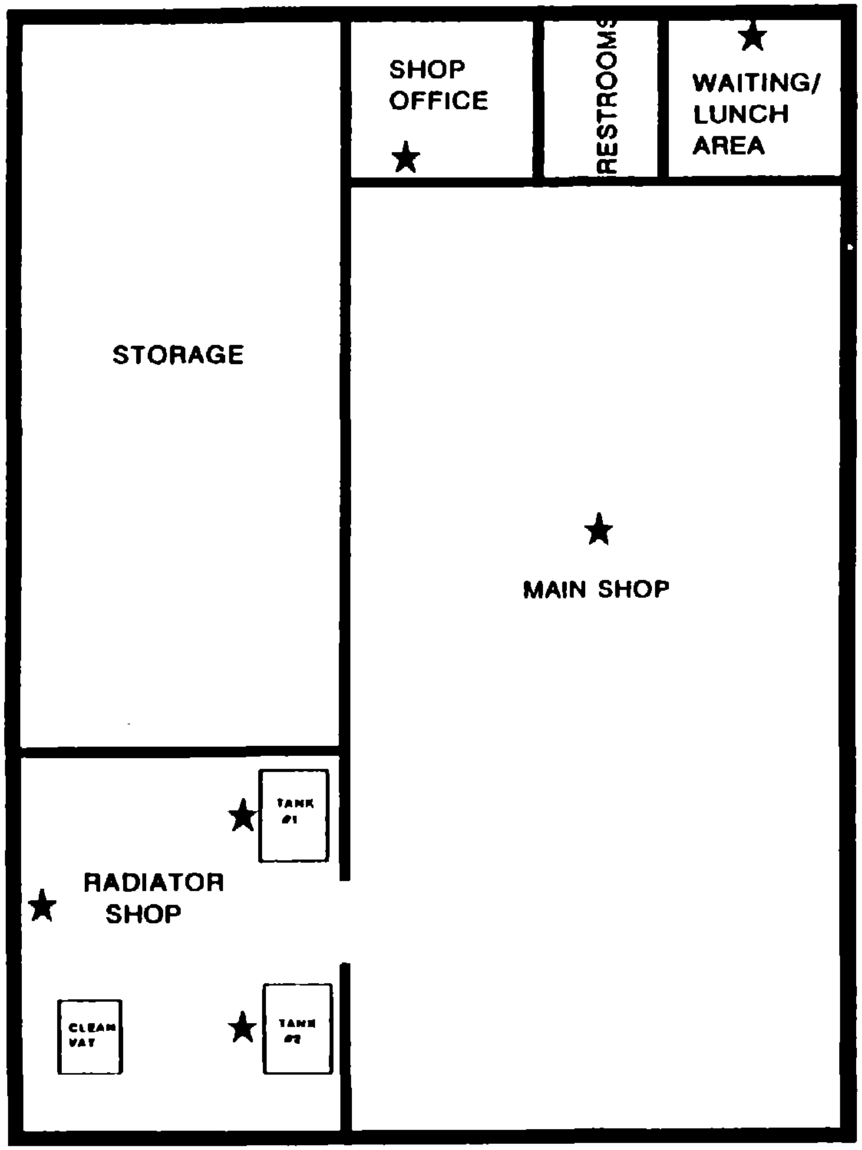

DIAGRAM OF RADIATOR SHOP

★ - AIR SAMPLING LOCATIONS

References

1. US Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. 1987. Manual of Analytical Methods, Third Edition. Cincinnati, OH.

2. US Department of Labor, Occupational Safety and Health Administration. 1978. Occupational Exposure to Lead--Final Standard. CFR 43:54353-54616.

3. US Department of Housing and Urban Development, Office of Public and Indian Housing. 1990. Lead-Based Paint: Interim Guidelines for Hazard Identification and Abatement in Public and Indian Housing. HUD-005646.

4. Telephone Conversation with Dick Gilchrist, Compliance Officer, Occupational Safety and Health Administration, Cincinnati Office (513) 841-4312, on December 20, 1991.

5. US Environmental Protection Agency, 1986. Pesticide Assessment Guidelines, Subdivision U: Applicator Exposure Monitoring. NTIS PB87-133286.

APPENDIX L Sample Results: Air Lead Concentrations

AIR LEAD CONCENTRATIONS

File=AIRCON.

SAMPLE #	DATE	SHOP	JOB/AREA	DURATION minutes	CONC ug/m3	NOTES	SUBJECT
Pb-1	07-08-91	1	RAD MECHANIC	221	2.2		ME
Pb-7	07-08-91	1	RAD MECHANIC	228	3.3		ME
Pb-51	07-09-91	1	RAD MECHANIC	442	18.5		ME
Pb-18	07-10-91	1	RAD MECHANIC	440	3.5		ME
Pb-40	07-11-91	1	RAD MECHANIC	377	5.4		ME
Pb-6	07-08-91	1	RAD MECHANIC	463	5.1		RJ
Pb-52	07-09-91	1	RAD MECHANIC	430	8.1		RJ
Pb-26	07-10-91	1	RAD MECHANIC	451	4.6		RJ
Pb-42	07-11-91	1	RAD MECHANIC	302	6.8		RJ
Pb-3	07-08-91	1	RAD MECHANIC	212	4.8		GW
Pb-5	07-08-91	1	RAD MECHANIC	218	10.6		GW
Pb-30	07-09-91	1	RAD MECHANIC	443	4.6		GW
Pb-28	07-10-91	1	RAD MECHANIC	434	8.0		GW
Pb-2	07-11-91	1	RAD MECHANIC	311	3.3		GW
Pb-21	07-09-91	1	RAD MECHANIC	7	7.1	S	ME
Pb-46	07-11-91	1	RAD MECHANIC	30	4.1	S	RJ
Pb-8	07-08-91	1	RAD SHOP-general	323	1.6		
Pb-17	07-09-91	1	RAD SHOP-general	401	1.3		
Pb-36	07-10-91	1	RAD SHOP-general	444	4.5		
Pb-41	07-11-91	1	RAD SHOP-general	492	1.3		
Pb-12	07-09-91	1	RAD SHOP-tank	449	3.4		ME
Pb-29	07-10-91	1	RAD SHOP-tank	455	4.4		ME
Pb-48	07-11-91	1	RAD SHOP-tank	505	2.0		ME
Pb-22	07-08-91	1	RAD SHOP-tank	451	2.2		RJ
Pb-47	07-11-91	1	RAD SHOP-tank	511	2.0		RJ
Pb-11	07-09-91	1	RAD SHOP-office	409	5.7		
Pb-27	07-10-91	1	RAD SHOP-office	394	1.6		
Pb-44	07-11-91	1	RAD SHOP-office	494	1.3		
Pb-23	07-08-91	1	MAIN OFFICE	469	0.1		
Pb-13	07-09-91	1	MAIN OFFICE	476	0.3		
Pb-39	07-09-91	1	MAIN OFFICE	456	0.1		
Pb-24	07-08-91	1	LUNCH AREA	469	0.2		
Pb-4	07-09-91	1	LUNCH AREA	479	0.1		
Pb-37	07-10-91	1	LUNCH AREA	456	0.1		
Pb-45	07-11-91	1	RAD SHOP-tank	487	1.8		GW
Pb-38	07-11-91	1	RAD SHOP-tank	488	1.5		RJ
Pb-43	07-11-91	1	RAD SHOP-general	494	0.7		
Pb-34	07-10-91	1	RAD SHOP-general	447	0.5		
Pb-9	07-10-91	1	RAD SHOP-general	423	1.2		
Pb-61	07-29-91	2	RAD MECHANIC	214	4.9		DR

AIR LEAD CONCENTRATIONS

File=AIRCON.

SAMPLE #	DATE	SHOP	JOB/AREA	DURATION minutes	CONC ug/m3	NOTES	SUBJECT
Pb-77	07-30-91	2	RAD MECHANIC	101	5.2		DR
Pb-75	07-30-91	2	RAD MECHANIC	52	1.0		DR
Pb-84	07-30-91	2	RAD MECHANIC	8	2.2		DR
Pb-90	07-30-91	2	RAD MECHANIC	7	<2.5	S	DR
Pb-85	07-30-91	2	RAD MECHANIC	205	<1.6	S	DR
Pb-89	07-30-91	2	RAD MECHANIC	19	1.9		DR
Pb-79	07-30-91	2	RAD MECHANIC	91	4.3		DR
Pb-83	07-30-91	2	RAD MECHANIC	45	2.3		DR
Pb-92	07-31-91	2	RAD MECHANIC	55	2.5		DR
Pb-100	07-31-91	2	RAD MECHANIC	158	1.7		DR
Pb-103	07-31-91	2	RAD MECHANIC	63	<0.3		DR
Pb-104	07-31-91	2	RAD MECHANIC	113	1.4		DR
Pb-99	07-31-91	2	RAD MECHANIC	72	<0.3		DR
Pb-112	08-01-91	2	RAD MECHANIC	195	3.4		DR
Pb-117	08-01-91	2	RAD MECHANIC	6	<2.9	S	DR
Pb-113	08-01-91	2	RAD MECHANIC	189	1.3		DR
Pb-118	08-01-91	2	RAD MECHANIC	119	6.0		DR
Pb-81	07-30-91	2	RAD MECHANIC	522	5.9		GR
Pb-96	07-31-91	2	RAD MECHANIC	388	7.1		GR
Pb-111	08-01-91	2	RAD MECHANIC	165	9.5		GR
Pb-116	08-01-91	2	RAD MECHANIC	348	3.0		GR
Pb-62	07-29-91	2	RAD MECHANIC	475	1.8		RR
Pb-76	07-30-91	2	RAD MECHANIC	522	2.1		RR
Pb-97	07-31-91	2	RAD MECHANIC	412	1.6		RR
Pb-110	08-01-91	2	RAD MECHANIC	413	1.0		RR
Pb-56	07-29-91	2	RAD SHOP-tank	491	1.0		DR
Pb-72	07-30-91	2	RAD SHOP-tank	546	0.1		DR
Pb-91	07-31-91	2	RAD SHOP-tank	521	1.3		DR
Pb-102	08-01-91	2	RAD SHOP-tank	511	1.3		DR
Pb-71	07-30-91	2	RAD SHOP-tank	539	0.7		RR
Pb-95	07-31-91	2	RAD SHOP-tank	517	0.5		RR
Pb-108	08-01-91	2	RAD SHOP-tank	508	1.2		RR
Pb-80	07-30-91	2	RAD SHOP-booth	506	0.5		GR
Pb-86	07-31-91	2	RAD SHOP-booth	531	1.4		GR
Pb-101	08-01-91	2	RAD SHOP-booth	509	2.0		GR
Pb-60	07-29-91	2	RAD SHOP-general	103	<0.1		
Pb-73	07-30-91	2	RAD SHOP-general	550	0.3		
Pb-94	07-31-91	2	RAD SHOP-general	529	0.5		
Pb-105	08-01-91	2	RAD SHOP-general	507	0.7		
Pb-55	07-29-91	2	RAD SHOP-office	501	0.9		

AIR LEAD CONCENTRATIONS

File=AIRCON.

SAMPLE #	DATE	SHOP	JOB/AREA	DURATION minutes	CONC ug/m3	NOTES	SUBJECT
Pb-68	07-30-91	2	RAD SHOP-office	554	1.5		
Pb-88	07-31-91	2	RAD SHOP-office	526	1.1		
Pb-107	08-01-91	2	RAD SHOP-office	545	1.1		
Pb-55	07-29-91	2	LUNCH AREA	501	0.9		
Pb-68	07-30-91	2	LUNCH AREA	554	1.5		
Pb-88	07-31-91	2	LUNCH AREA	526	1.1		
Pb-107	08-01-91	2	LUNCH AREA	545	1.1		
Pb-58	07-29-91	2	OUTSIDE-lev exhaust	481	<0.1		
Pb-69	07-30-91	2	OUTSIDE-lev exhaust	548	0.1		
Pb-93	07-31-91	2	OUTSIDE-lev exhaust	526	0.2		
Pb-106	08-01-91	2	OUTSIDE-lev exhaust	525	0.1		
Pb-70	07-29-91	2	BACKGROUND	501	<0.1		
Pb-67	07-30-91	2	BACKGROUND	549	<0.1		
Pb-87	07-31-91	2	BACKGROUND	528	<0.1		
Pb-98	08-01-91	2	BACKGROUND	525	<0.1		
Pb-20	07-08-91	1	BACKGROUND	460	<0.1		
Pb-19	07-09-91	1	BACKGROUND	474	<0.1		
Pb-35	07-10-91	1	BACKGROUND	453	<0.1		
Pb-138	08-19-91	3	RAD MECHANIC	42	433.0	S	DP
Pb-145	08-19-91	3	RAD MECHANIC	404	3.4		DP
Pb-166	08-21-91	3	RAD MECHANIC	56	810.0	S	DP
Pb-164	08-21-91	3	RAD MECHANIC	19	261.0	S	DP
Pb-160	08-21-91	3	RAD MECHANIC	116	208.0		DP
Pb-172	08-21-91	3	RAD MECHANIC	54	13.5		DP
Pb-152	08-19-91	3	RAD MECHANIC	34	352.0	S	CC
Pb-144	08-20-91	3	RAD MECHANIC	42	94.5	S	CC
Pb-157	08-20-91	3	RAD MECHANIC	325	1.0		CC
Pb-169	08-21-91	3	RAD MECHANIC	15	104.0	S	CC
Pb-168	08-21-91	3	RAD MECHANIC	62	<0.4		CC
Pb-159	08-21-91	3	RAD MECHANIC	118	309.0		CC
Pb-171	08-21-91	3	RAD MECHANIC	122	122.0		CC
Pb-139	08-19-91	3	RAD SHOP-general	463	0.7		
Pb-153	08-20-91	3	RAD SHOP-general	472	0.6		
Pb-161	08-21-91	3	RAD SHOP-general	467	1.8		
Pb-154	08-20-91	3	RAD SHOP-tank	475	119.0		
Pb-163	08-21-91	3	RAD SHOP-tank	466	180.0		
Pb-167	08-21-91	3	RAD SHOP-tank	463	132.0		
Pb-131	08-19-91	3	RAD SHOP-general	459	16.8		
Pb-143	08-20-91	3	RAD SHOP-general	484	3.0		
Pb-158	08-21-91	3	RAD SHOP-general	469	95.6		

AIR LEAD CONCENTRATIONS

File=AIRCON.

SAMPLE #	DATE	SHOP	JOB/AREA	DURATION minutes	CONC ug/m3	NOTES	SUBJECT
Pb-142	08-19-91	3	MAIN OFFICE	462	0.8		
Pb-151	08-20-91	3	MAIN OFFICE	487	0.7		
Pb-155	08-21-91	3	MAIN OFFICE	468	1.0		
Pb-137	08-19-91	3	LUNCH AREA	465	0.9		
Pb-135	08-20-91	3	LUNCH AREA	488	0.6		
Pb-156	08-21-91	3	LUNCH AREA	471	0.6		
Pb-134	08-19-91	3	BACKGROUND	464	<0.1		
Pb-150	08-20-91	3	BACKGROUND	452	<0.1		
Pb-162	08-21-91	3	BACKGROUND	467	<0.1		

S= soldered entire sample duration
<= less than limit of detection (LOD)
All sample concentrations are corrected for field blanks as follows:
Shop 1: .00 ug (Method 7082); .00 ug (Method 7105)
Shop 2: .00 ug (Method 7082);-.22 ug (Method 7105)
Shop 3:-.06 ug (Method 7105)(all samples analyzed by 7105)

APPENDIX M Sample Results: Time-Weighted Average Exposures

TIME-WEIGHTED AVERAGE (TWA) AIR LEAD EXPOSURES (uG/M3)

File = TWAEXP.

DATE	SHOP	JOB	DURATION (minutes)	TWA (over duration)	TWA (8-hr)	SUBJECT
07/08/91	1	RAD MECHANIC	449	2.8	2.6	ME
07/09/91	1	RAD MECHANIC	442	18.5	17.0	ME
07/10/91	1	RAD MECHANIC	440	3.5	3.2	ME
07/11/91	1	RAD MECHANIC	377	5.4	4.2	ME
07/08/91	1	RAD MECHANIC	463	5.1	4.9	RJ
07/09/91	1	RAD MECHANIC	430	8.1	7.3	RJ
07/10/91	1	RAD MECHANIC	451	4.6	4.3	RJ
07/11/91	1	RAD MECHANIC	302	6.8	4.3	RJ
07/08/91	1	RAD MECHANIC	430	7.8	6.9	GW
07/09/91	1	RAD MECHANIC	443	4.6	4.2	GW
07/10/91	1	RAD MECHANIC	434	8.0	7.2	GW
07/11/91	1	RAD MECHANIC	311	3.3	2.1	GW
07/29/91	2	RAD MECHANIC	214	4.9	2.2	DR
07/30/91	2	RAD MECHANIC	528	2.8	2.8	DR
07/31/91	2	RAD MECHANIC	481	1.3	1.3	DR
08/01/91	2	RAD MECHANIC	509	3.2	3.2	DR
07/30/91	2	RAD MECHANIC	522	5.9	5.9	GR
07/31/91	2	RAD MECHANIC	388	7.1	5.8	GR
08/01/91	2	RAD MECHANIC	513	5.1	5.1	GR
07/29/91	2	RAD MECHANIC	475	1.8	1.8	RR
07/30/91	2	RAD MECHANIC	522	2.1	2.1	RR
07/31/91	2	RAD MECHANIC	412	1.6	1.4	RR
08/01/91	2	RAD MECHANIC	413	1.0	0.9	RR
08/19/91	3	RAD MECHANIC	446	43.9	40.8	DP
08/21/91	3	RAD MECHANIC	245	307.0	157.0	DP
08/19/91	3	RAD MECHANIC	34	352.0	24.9	CC
08/20/91	3	RAD MECHANIC	367	11.7	9.0	CC
08/21/91	3	RAD MECHANIC	248	180.0	92.7	CC

APPENDIX N Sample Results: Surface Lead Concentrations

SURFACE LEAD CONCENTRATIONS

File = PBWIPE.

SAMPLE #	DATE	SHOP	JOB/AREA	AREA (cm2)	AMT FOUND (ug)	CONC (ug/m2)	NOTES	SUBJECT
WS-51	07-08-91	1	REPAIR TANK:edge	500	25000	500000		
WS-23	07-10-91	1	REPAIR TANK:edge	200	6279	314800		
WS-12	07-10-91	1	REPAIR TANK:edge	80	72	9000		
WS-35	07-08-91	1	SHOP OFFICE:desktop	225	24	1067		
WS-40	07-08-91	1	SHOP OFFICE:doorknob	79	116	14777		
WS-36	07-08-91	1	RAD SHOP:gloves	50	146	29200	inside	ME
WS-31	07-08-91	1	RESTROOM:toilet flusher	19	25	13300		
WS-38	07-08-91	1	LUNCHROOM:tabletop	625	6	96		
WS-49	07-08-91	1	SHOP OFF:telephone	80	676	84500		
WS-55	07-09-91	1	FORKLIFT:steering wheel	200	106	5300		
WS-41	07-09-91	1	RAD SHOP:telephone	80	136	17000		
WS-22	07-09-91	1	RAD SHOP:tool handle	100	156	15600		
WS-01	07-10-91	1	PERSONAL VEHICLE:armrest	300	39	1300	driver's	RJ
WS-25	07-10-91	1	PERSONAL VEHICLE:seat	625	61	976	driver's	GW
WS-93	07-11-91	1	PERSONAL VEHICLE:armrest	300	92	3066	driver's	ME
WS-114	07-11-91	1	IND HYGIENIST:hands	820	456	5560		GP
WS-47	07-09-91	1	RAD MECH:hands(@lunch)	820	1196	14585	prewash	RJ
WS-03	07-10-91	1	RAD MECH:hands(@lunch)	820	2596	31659	prewash	RJ
WS-98	07-11-91	1	RAD MECH:hands(@lunch)	820	1096	13366	prewash	RJ
WS-60	07-09-91	1	RAD MECH:hands(@lunch)	820	776	9463	prewash	ME
WS-15	07-10-91	1	RAD MECH:hands(@lunch)	820	496	6049	prewash	ME
WS-103	07-11-91	1	RAD MECH:hands(@lunch)	820	776	9463	prewash	ME
WS-52	07-09-91	1	RAD MECH:hands(@lunch)	820	686	8366	prewash	GW
WS-29	07-10-91	1	RAD MECH:hands(@lunch)	820	1196	14585	prewash	GW

SURFACE LEAD CONCENTRATIONS

File = PBWIPE.

SAMPLE #	DATE	SHOP	JOB/AREA	AREA (cm2)	AMT FOUND (ug)	CONC (ug/m2)	NOTES	SUBJECT
WS-91	07-11-91	1	RAD MECH:hands(@lunch)	820	876	10683	prewash	GW
WS-53	07-08-91	1	RAD MECH:hands(@endshift)	820	756	9220	prewash	RJ
WS-59	07-09-91	1	RAD MECH:hands(@endshift)	820	1096	13365	prewash	RJ
WS-16	07-10-91	1	RAD MECH:hands(@endshift)	820	3396	41415	prewash	RJ
WS-20	07-11-91	1	RAD MECH:hands(@endshift)	820	2496	30440	prewash	RJ
WS-46	07-08-91	1	RAD MECH:hands(@endshift)	820	736	8975	prewash	ME
WS-26	07-09-91	1	RAD MECH:hands(@endshift)	820	486	5927	prewash	ME
WS-10	07-10-91	1	RAD MECH:hands(@endshift)	820	516	6293	prewash	ME
WS-11	07-11-91	1	RAD MECH:hands(@endshift)	820	436	5317	prewash	ME
WS-32	07-08-91	1	RAD MECH:hands(@endshift)	820	816	9950	prewash	GW
WS-04	07-09-91	1	RAD MECH:hands(@endshift)	820	406	4950	prewash	GW
WS-17	07-10-91	1	RAD MECH:hands(@endshift)	820	716	8730	prewash	GW
WS-09	07-11-91	1	RAD MECH:hands(@endshift)	820	1196	14585	prewash	GW
WS-37	07-08-91	1	RAD MECH:forehead	25	17	207		RJ
WS-13	07-09-91	1	RAD MECH:forehead	25	14	170		RJ
WS-28	07-10-91	1	RAD MECH:forehead	25	5	60		RJ
WS-06	07-11-91	1	RAD MECH:forehead	25	4	49		RJ
WS-39	07-08-91	1	RAD MECH:forehead	25	20	244		ME
WS-57	07-09-91	1	RAD MECH:forehead	25	40	488		ME
WS-24	07-10-91	1	RAD MECH:forehead	25	5	60		ME
WS-21	07-11-91	1	RAD MECH:forehead	25	6	73		ME
WS-33	07-08-91	1	RAD MECH:forehead	25	39	475		GW
WS-27	07-09-91	1	RAD MECH:forehead	25	10	122		GW
WS-02	07-10-91	1	RAD MECH:forehead	25	4	49		GW

SURFACE LEAD CONCENTRATIONS

File = PBWIPE.

SAMPLE #	DATE	SHOP	JOB/AREA	AREA (cm2)	AMT FOUND (ug)	CONC (ug/m2)	NOTES	SUBJECT
WS-08	07-11-91	1	RAD MECH:forehead	25	4	49		GW
WS-92	07-29-91	2	RAD MECH:hands(@lunch)	820	130	1585	prewash	RR
WS-160	07-30-91	2	RAD MECH:hands(@lunch)	820	53	646	prewash	RR
WS-87	07-31-91	2	RAD MECH:hands(@lunch)	820	240	2927	prewash	RR
WS-142	08-01-91	2	RAD MECH:hands(@lunch)	820	10	122	postwash	RR
WS-94	07-29-91	2	RAD MECH:hands(@lunch)	820	330	4024	prewash	SC
WS-157	07-30-91	2	RAD MECH:hands(@lunch)	820	330	4024	prewash	SC
WS-88	07-31-91	2	RAD MECH:hands(@lunch)	820	180	2195	prewash	SC
WS-145	08-01-91	2	RAD MECH:hands(@lunch)	820	14	170	postwash	SC
WS-101	07-29-91	2	RAD MECH:hands(@lunch)	820	210	2560	prewash	DR
WS-155	07-30-91	2	RAD MECH:hands(@lunch)	820	460	5610	prewash	DR
WS-82	07-31-91	2	RAD MECH:hands(@lunch)	820	200	2440	prewash	DR
WS-121	08-01-91	2	RAD MECH:hands(@lunch)	820	34	415	postwash	DR
WS-152	07-30-91	2	RAD MECH:hands(@lunch)	820	320	3900	prewash	GR
WS-85	07-31-91	2	RAD MECH:hands(@lunch)	820	170	2075	prewash	GR
WS-124	08-01-91	2	RAD MECH:hands(@lunch)	820	26	320	postwash	GR
WS-110	07-29-91	2	RAD MECH:hands(@endshift)	820	1100	13415	prewash	RR
WS-75	07-30-91	2	RAD MECH:hands(@endshift)	820	320	3900	prewash	RR
WS-64	07-31-91	2	RAD MECH:hands(@endshift)	820	670	8170	prewash	RR
WS-148	08-01-91	2	RAD MECH:hands(@endshift)	820	930	11340	prewash	RR
WS-119	07-29-91	2	RAD MECH:hands(@endshift)	820	34	414	postwash	RR
WS-77	07-30-91	2	RAD MECH:hands(@endshift)	820	21	256	postwash	RR
WS-133	07-31-91	2	RAD MECH:hands(@endshift)	820	28	341	postwash	RR
WS-150	08-01-91	2	RAD MECH:hands(@endshift)	820	13	160	postwash	RR

SURFACE LEAD CONCENTRATIONS

File = PBWIPE.

SAMPLE #	DATE	SHOP	JOB/AREA	AREA (cm2)	AMT FOUND (ug)	CONC (ug/m2)	NOTES	SUBJECT
WS-120	07-29-91	2	RAD MECH:hands(@endshift)	820	1500	18290	prewash	SC
WS-67	07-30-91	2	RAD MECH:hands(@endshift)	820	240	2930	prewash	SC
WS-90	07-31-91	2	RAD MECH:hands(@endshift)	820	530	6460	prewash	SC
WS-123	08-01-91	2	RAD MECH:hands(@endshift)	820	1800	21950	prewash	SC
WS-76	07-30-91	2	RAD MECH:hands(@endshift)	820	11	135	postwash	SC
WS-139	07-31-91	2	RAD MECH:hands(@endshift)	820	60	730	postwash	SC
WS-122	08-01-91	2	RAD MECH:hands(@endshift)	820	56	680	postwash	SC
WS-100	07-29-91	2	RAD MECH:hands(@endshift)	820	310	3780	prewash	DR
WS-61	07-30-91	2	RAD MECH:hands(@endshift)	820	780	9512	prewash	DR
WS-72	07-31-91	2	RAD MECH:hands(@endshift)	820	450	5488	prewash	DR
WS-137	08-01-91	2	RAD MECH:hands(@endshift)	820	720	8780	prewash	DR
WS-108	07-29-91	2	RAD MECH:hands(@endshift)	820	97	1183	postwash	DR
WS-65	07-30-91	2	RAD MECH:hands(@endshift)	820	110	1341	postwash	DR
WS-141	07-31-91	2	RAD MECH:hands(@endshift)	820	46	561	postwash	DR
WS-146	08-01-91	2	RAD MECH:hands(@endshift)	820	23	280	postwash	DR
WS-70	07-30-91	2	RAD MECH:hands(@endshift)	820	1000	12195	prewash	GR
WS-86	07-31-91	2	RAD MECH:hands(@endshift)	820	200	2440	prewash	GR
WS-143	08-01-91	2	RAD MECH:hands(@endshift)	820	1300	15853	prewash	GR
WS-62	07-30-91	2	RAD MECH:hands(@endshift)	820	13	159	postwash	GR
WS-125	07-31-91	2	RAD MECH:hands(@endshift)	820	8	976	postwash	GR
WS-129	08-01-91	2	RAD MECH:hands(@endshift)	820	20	2439	postwash	GR
WS-106	07-29-91	2	RAD MECH:forehead	25	2	800		RR
WS-81	07-30-91	2	RAD MECH:forehead	25	4	1600		RR
WS-131	07-31-91	2	RAD MECH:forehead	25	2	800		RR

SURFACE LEAD CONCENTRATIONS

File = PBWIPE.

SAMPLE #	DATE	SHOP	JOB/AREA	AREA (cm2)	AMT FOUND (ug)	CONC (ug/m2)	NOTES	SUBJECT
WS-112	07-29-91	2	RAD MECH:forehead	25	4	1600		DR
WS-63	07-30-91	2	RAD MECH:forehead	25	12	4800		DR
WS-126	07-31-91	2	RAD MECH:forehead	25	4	1600		DR
WS-69	07-29-91	2	RAD MECH:forehead	25	10	4000		GR
WS-128	07-30-91	2	RAD MECH:forehead	25	15	6000		GR
WS-117	07-31-91	2	RAD SHOP:telephone	80	150	18750		
WS-163	07-30-91	2	RESTROOM:lightswitch	77	140	18180		
WS-169	07-30-91	2	RESTROOM:toilet flusher	19	10	5263		
WS-174	07-30-91	2	SHOP OFFICE:telephone	80	31	3875		
WS-171	07-30-91	2	SHOP OFFICE:desktop	100	4	410		
WS-177	07-30-91	2	RAD MECH:streetshoes	50	100	20000	top	DR
WS-175	07-31-91	2	RAD MECH:streetshoes	50	230	46000	top	RR
WS-180	07-31-91	2	PERSONAL VEHICLE:seat	100	7	700	driver's	RR
WS-164	07-31-91	2	PERSONAL VEHICLE:armrest	100	92	9200	driver's	RR
WS-170	07-31-91	2	PERSONAL VEHICLE:floormat	100	960	96000	driver's	RR
WS-178	07-31-91	2	PERSONAL VEHICLE:seat	100	21	2100	passenger's	RR
WS-161	07-31-91	2	PERSONAL VEHICLE:gaspedal	50	98	19600		RR
WS-165	07-31-91	2	PERSONAL VEHICLE:armrest	100	190	19000	driver's	DR
WS-172	07-31-91	2	PERSONAL VEHICLE:floormat	100	680	68000	driver's	DR
WS-66	07-31-91	2	PERSONAL VEHICLE:gaspedal	50	340	68000		DR
WS-179	07-31-91	2	PERSONAL VEHICLE:dashboard	100	210	21000		DR
WS-79	07-31-91	2	SHOP VEHICLE:steeringwheel	200	410	20500		
WS-84	07-31-91	2	SHOP VEHICLE:seat	100	14	1400	driver's	
WS-208	08-19-91	3	RAD MECH:hands(@endshift)	820	130	1583	prewash	DP

SURFACE LEAD CONCENTRATIONS

File = PBWIPE.

SAMPLE #	DATE	SHOP	JOB/AREA	AREA (cm2)	AMT FOUND (ug)	CONC (ug/m2)	NOTES	SUBJECT
WS-190	08-21-91	3	RAD MECH:hands(@endshift)	820	6400	78050	prewash	DP
WS-194	08-21-91	3	RAD MECH:hands(@endshift)	820	4200	51220	prewash	CC
WS-188	08-19-91	3	LUNCHROOM:tabletop	50	4	800		
WS-195	08-19-91	3	RESTROOM:faucet	50	4	800		
WS-210	08-19-91	3	SHOP OFF:desktop	75	7	933		
WS-181	08-19-91	3	RAD SHOP:phone	80	61	7625		
WS-202	08-21-91	3	RAD SHOP:doorknob	79	400	50633		

All concentrations are corrected for field blanks as follows:

Shop 1: -4.0 ug (Method 7082); -0.2 ug (Method 7105)
Shop 2: 0.0 ug (Method 7082); -0.1 ug (Method 7105)
Shop 3: -.19 ug (Method 7105)(all samples were analyzed by 7105)
Note that all correction factors were rounded off to the nearest whole ug

APPENDIX O NIOSH Recommended Respirators for Exposure to Lead

NIOSH-recommended respiratory protection for workers exposed to inorganic lead

Condition	Minimum respiratory protection*
≤0.5 mg/m^3† (10 × PEL‡)	Any air-purifying respirator with a high-efficiency particulate filter
≤1.25 mg/m^3 (25 × PEL)	Any powered, air-purifying respirator with a high-efficiency particulate filter, or
	Any supplied-air respirator equipped with a hood or helmet and operated in a continuous-flow mode (for example, type CE abrasive blasting respirators)
≤2.5 mg/m^3 (50 × PEL)	Any air-purifying, full-facepiece respirator with a high-efficiency particulate filter, or
	Any powered, air-purifying respirator with a tight-fitting facepiece and a high-efficiency particulate filter
≤50 mg/m^3 (1,000 × PEL)	Any supplied-air respirator equipped with a half-mask and operated in a pressure-demand or other positive-pressure mode
≤100 mg/m^3 (2,000 × PEL)	Any supplied-air respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode
Planned or emergency entry into environments containing unknown concentrations or concentrations above 100 mg/m^3 (2,000 × PEL)	Any self-contained breathing apparatus equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode, or
	Any supplied-air respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive-pressure mode
Firefighting	Any self-contained breathing apparatus equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode
Escape only	Any air-purifying, full-facepiece respirator with a high-efficiency particulate filter, or
	Any appropriate escape-type, self-contained breathing apparatus

*Only NIOSH/MSHA-approved equipment should be used.
†Less than or equal to 0.5 mg/m^3.
‡Multiple of the OSHA PEL for general industry.

Taken from: NIOSH Alert: Preventing Leading Poisoning in Construction Workers[34]

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7. Author(s) Piacitelli, G. M.	8. Performing Organization Rept. No. IWSB-182-5
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15. Supplementary Notes

16. Abstract (Limit: 200 words) In an attempt to determine worker exposure to lead (7439921) in radiator repair shops, area and personal sampling was performed at three locations in Cincinnati, Ohio. Altogether, 129 air samples and 126 wipe samples were collected. The highest air concentrations were near the repair stations where mechanics work with molten lead based solder. Two shops used local exhaust ventilation and had effectively controlled worker exposure to airborne lead. Exposures in a third shop where there was no local ventilation were frequently above the permissible exposure limit (50 micrograms/cubic meter). Lead contamination on work surfaces was as high as 500,000 micrograms/square meter. Lead was also found in lunch areas, on the hands of workers before and after washing, on street shoes and in personal vehicles. The author recommended steps to be taken to reduce this contamination level, including the installation of an effective local exhaust ventilation system, the mandatory use of protective equipment, a strict adherence to personal and environmental hygiene, an enforced prohibition of eating and smoking in all lead contaminated areas, the implementation of routine environmental and medical monitoring programs, and training to increase the awareness of the problems associated with using lead.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms NIOSH-Publication, NIOSH-Author, Heavy-metals, IWSB-182-5, Region-5, NIOSH-Survey, Field-Study, Skin-exposure, Environmental-contamination, Metal-dusts, Dust-inhalation, Automobile-repair-shops, Occupational-exposure

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