

# **An occupational hygiene assessment of dermal inorganic lead exposures in primary and intermediate user industries**

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Inorganic lead compounds are not normally considered to be a significant risk by skin exposure, the main routes of concern being inhalation of airborne dust and inadvertent ingestion, for example by hand-to-mouth contact. There is a lack of dermal exposure data for industrial workers and this information was required for a regulatory risk assessment purposes. The main aim of this study was to establish typical dermal lead exposures for lead production workers. A secondary aim was to investigate the potential for take-home contamination on the skin or hair, and make a limited evaluation of the potential for ingestion exposure due to hand-to-mouth contact or from deposition of contamination to the perioral region.

Workplace surveys were carried out in a lead refinery and in a company producing litharge and other lead-containing powders, and a range of production tasks were studied. Dermal exposure samples were collected using a removal method, using commercial moist wipes to recover the lead deposits from measured areas of skin. The test procedures were validated before the workplace surveys and the average recovery efficiency for the sample preparation and analysis procedure was close to 100%.

There were 32 complete sets of exposure measurements, from 32 different workers. Over 440 individual dermal exposure samples were collected for lead analysis. In addition, 14 sets of sample results from a zinc/lead refinery not previously reported, were reviewed and incorporated into this report.

Dermal lead levels on the hands of those workers involved in molten metal areas or in ancillary operations were generally  $<10 \mu\text{g}/\text{cm}^2$ . For the dustier tasks, average dermal lead exposures for the hands were generally within the range  $10 - 200 \mu\text{g}/\text{cm}^2$ . The observed pattern of exposure would be expected given the relatively mobile nature of the lead powder products and lead-concentrate dusts.

It is concluded that overall, the dermal exposures were low and that this is largely due to the engineering controls applied to the production processes generally, combined with specific hygiene measures such as the consistent use of personal protective equipment.



# CONTENTS

1.	INTRODUCTION	1
2.	AIMS	3
3.	METHODS	5
3.1	Sampling strategy	5
3.2	Dermal sampling method	5
3.3	Analysis	7
3.4	Method validation	8
3.5	Statistical methods	9
3.6	Evaluation of task-based dermal exposures using the EASE model	9
4.	WORKPLACE DESCRIPTIONS	11
4.1	Zinc/lead refinery	11
4.2	Lead refinery	14
4.3	Lead chemical production	16
5.	RESULTS	21
5.1	Method validation	21
5.2	Results of dermal sampling in the workplace	25
5.3	Analysis of dermal exposure data by industry and EASE category	31
5.4	Results of residual contamination from hair and finger nails	38
5.5	Correlation of exposure data by anatomical area	40
6.	DISCUSSION	49
7.	CONCLUSIONS	53
8.	STATEMENT OF QUALITY	55
9.	ACKNOWLEDGEMENTS	57
10.	REFERENCES	59
	APPENDIX 1 JOB ACTIVITY RECORDS	61



# 1. INTRODUCTION

Lead is a common environmental contaminant, which is largely the result of its exploitation since prehistoric times. Lead usage has increased progressively with industrialization and rose dramatically with the use of lead-acid batteries and leaded fuel for automobiles. The main use of lead now is in batteries and lead-based chemicals such as pigments and stabilisers used in the manufacture of PVC. Occupations in which the highest potential exposure to lead exists in the EU include primary and secondary smelting, lead sheet production, production of lead-acid batteries, pigment production, construction and demolition. The important routes of occupational exposure from inorganic forms of lead are from inhalation of dust and fumes. It is also recognised that inadvertent ingestion of lead dust can be a significant route of exposure (Karita *et al.*, 1997). Consequently, it is usual practice for industrial lead users to implement strict personal hygiene programmes in the workplace in order to minimise the spread of contamination.

Similar to other EU countries, work with lead in the UK is regulated by the Control of Lead at Work Regulations 2002. The main requirements of these regulations include duties to prevent or control exposure; provide designated clean and dirty areas including washing and showering facilities; carry out regular air monitoring, medical surveillance, including routine lead-in-blood tests. In the UK, a lead in blood 'Action Level' of currently 50 µg/dl is set (for male workers) and the occupational exposure limit for airborne lead is 0.15 mg/m<sup>3</sup>. Other European countries have similar controls in place, with occupational exposure limits for airborne lead as low as 0.1 mg/m<sup>3</sup>. Further, in some countries a blood lead threshold level of 40 µg/dl is due to be implemented.

Inorganic lead compounds are not normally considered to be a significant risk by skin exposure (Bress and Bidanset 1991). This is mainly because the most common forms of lead have low rates of permeation through the skin. One study measured permeation rates by *in vitro* testing of human skin samples using red lead (Pb<sub>3</sub>O<sub>4</sub>), litharge (PbO) and for comparison, tetraethyl lead (C<sub>2</sub>H<sub>5</sub>)<sub>4</sub>Pb, which is readily absorbed through the skin. The permeation coefficients for red lead and litharge were 0.00064 and 0.00044 respectively. The corresponding result for tetraethyl lead was 0.675 (Watson, 1998). However, the rate of permeation is dependent on the particular form of lead and the rates are likely to be higher for more soluble forms of inorganic lead (Stauber *et al.*, 1994). Apart from this, there is no evidence to suggest that dermal lead exposure causes local skin effects such as allergic dermatitis.

EU regulatory risk assessments carried out as part of the Existing Substance Regulations (CEC, 1993) requires that all routes of exposure are assessed, and where there are no existing data, default levels of exposure are used either based on analogous data sets or from exposure models, such as EASE (HSE, 1996).

The Estimation and Assessment of Substance Exposure (EASE) model was developed by the UK Health and Safety Executive (HSE) to assist exposure assessment for new substances. The model is based on a series of logical criteria contained within a computer-based expert system and can be used to predict exposures using task and situation-specific information about the substance and methods of control. The dermal exposure model predicts the potential exposure to the hands and forearms expressed as a mass per unit area of exposed skin per day (mg/cm<sup>2</sup>/day). This evaluation is based on information about the method and frequency of handling of contaminated objects and assumes an exposed anatomical area of approximately 2,000 cm<sup>2</sup>. The two principal criteria used in the EASE model to predict dermal exposure are: the dermal contact level (possible values – *none, incidental, intermittent and extensive*) and

the pattern of use (*closed system, with limited use* – termed '*inclusion into matrix or non-dispersive use*' in the model, and *uncontrolled release* – termed '*wide dispersive use*'). The predictions or 'end-points' are expressed as exposure ranges, which can take five different values from 'very low' to 5 - 15 mg/cm<sup>2</sup>/day.

A comprehensive review of the EASE model has recently been carried out (Creely *et al.*, 2005) and the EASE model has been shown to generate predicted exposures which, in general are overly conservative. This has been demonstrated for the dermal exposure model in a study concerned with dermal zinc exposure (Hughson and Cherrie 2005). The data from this study was partly incorporated into the EU regulatory risk assessment for zinc metal (ECB, 2004) and zinc compounds including zinc oxide and zinc chloride. The possibility of using these exposure data as an analogy set for default dermal exposure levels for other metal industries, including lead, is currently being explored. However, since the working practices in the zinc industry are likely to differ from those in the lead industry sectors, such an analogy may again overestimate exposures.

Therefore, in order to accurately evaluate actual dermal exposure levels within the main industry sectors, a dermal exposure monitoring survey was designed and implemented for two different European workplaces using lead or lead compounds. One of these included a company which manufactured litharge (PbO) and used this to produce a wide variety of lead chemicals used as stabilisers or pigments for plastic manufacturing. The second company refined lead concentrates by a smelting process to produce lead metal ingots. Additional data were obtained from a third site which was surveyed as part of the dermal zinc exposure assessment previously referred to. These data were collected from a zinc/lead refinery, in which lead is a major component of the raw materials used. Apart from zinc, lead was recovered as part of the refining process and the site was therefore designated as a lead production site, regulated under The Control of Lead at Work Regulations 2002.

The exposure measurements for the current study were collected using practically the same wipe sampling method, as previously reported (Hughson and Cherrie 2005), to enable the two sets of measurements to be compared.

## 2. AIMS

The main aim of this study was to supplement existing scientific knowledge about the levels of occupational dermal lead exposure in the lead refining and lead chemical producing industries.

To achieve this aim we addressed the following key objectives:

- To assess occupational dermal exposures to inorganic lead compounds, taking into account the working practices and conditions within each workplace.
- To collect measurements of actual dermal exposures; defined as the level of contamination on the skin surface, averaged over the relevant exposure period.
- To compare measurements of dermal exposures against exposure predictions produced by the EASE model where applicable.
- To observe and measure task-specific exposures for common industrial tasks, where possible. This included bag packing and bag emptying work as well as raw material handling, since these may be considered to represent worst case exposure scenarios for EU risk assessment purposes.
- To investigate the potential for take-home contamination on the skin or hair, and make a limited investigation into the potential for ingestion exposure due to hand-to-mouth contact or from deposition of contamination to the perioral region.



## 3. METHODS

### 3.1 SAMPLING STRATEGY

It is recognised that there is a wide variability in potential dermal exposures within and between tasks and individuals (Kromhout *et al.*, 2004). It is therefore desirable to monitor as many different workers as possible within each exposure scenario under consideration. However, due to the high level of automation common in modern industrial workplaces, this is not always a practical option. In this case it was necessary to select the process operators with significant potential for dermal exposure and to repeat these measurements over consecutive days, where necessary, in order to ensure a sufficient number of measurements.

Dermal exposure assessment can be done by measuring *potential dermal exposure* or *actual dermal exposure*. Potential dermal exposure is the amount of contaminant landing on the outer clothing and on the exposed surfaces of the skin. Actual dermal exposure is the amount of contamination actually reaching the skin. Exposure by this route is mediated by the protective clothing and hygiene programmes designed to minimise transfer of contamination to the skin. Measurements of potential dermal exposure are often used for exposure modelling purposes and extrapolating exposures for similar workplace scenarios. Measurements of actual dermal exposures are more useful for risk assessment of specific situations and thus we have used a removal method to produce estimates of actual dermal lead exposure.

In this case, dermal exposures were measured using moist wipes. These wipes were used to remove residual contamination from predetermined skin areas at different intervals over the working shift. Samples were collected before washing so that they were representative of the level of skin contamination during the working day.

### 3.2 DERMAL SAMPLING METHOD

Wipe samples were collected from the skin using a commercial moist wipe (Jeyes 'Sticky Fingers' Wet Ones) and an acetate template with an open aperture of 25 cm<sup>2</sup> pressed onto the relevant anatomical area at the time of sampling. Each sample comprised three sequential wipes from the anatomical area being sampled.

Wipe samples were collected from the palm and back of each hand and from both forearms. This was done before rest breaks so that contamination was not lost from the skin by washing. Samples of skin contamination were collected at three different intervals over the working day in order to assess contamination while at work.

Additional samples were collected from the side of the neck, face (perioral region) and chest. The perioral face samples were used to provide an estimate of exposure for the head and also help make informed estimates about the potential for ingestion exposure. The sample from the chest was used to assess the degree of contamination under work clothes. These samples were collected once, near the end of the shift, i.e. before the afternoon break or before showering. It was not possible to use the acetate template for collecting the sample from the perioral region. In this case, the sample was collected by wiping around the mouth region. For the purposes of this assessment it is assumed that this area was equivalent to 25 cm<sup>2</sup>.

The wipe samples from the palms and backs of the hands were collected in separate containers. The samples for the left and right forearms were bulked together into a third container. These were kept separate from other samples collected at different times of the day to enable an assessment to be made of the variability of exposure across the working shift.

The dermal exposure level for each worker was taken to be the surface loading of lead calculated as a mass per unit area of skin. Since the aim of this study was to produce measurements of actual dermal lead exposure, it was assumed that the best measure of this would be an average value of the three different sample sets collected for the hands and/or forearms. Furthermore, workers were known to regularly wash their hands as part of their normal hygiene procedure, so an average value of the three sample sets was considered to be representative of what would be present on the skin over the course of the working shift.

Samples of contamination from under finger nails were collected before the mid-day break and after washing at the end of the shift. This was supervised, but self-administered by the worker. The subject was provided with a clean, wooden manicure stick, a clean wipe and a clean sample bottle on each occasion. The subject was asked to use the manicure stick to scrape out any residues from each finger nail and to wipe this onto the wipe. This was placed into the sample container by the researcher. Lastly, a wipe sample was collected from the hair of each subject before going home. This was collected by wiping the head and hair region using three sequential wipes as before. These two latter procedures were conducted for a preliminary assessment of the efficacy of personal cleaning procedures and the potential for “work-home transfer”.

The sampling procedure is summarised in Table 1, below:

**Table 1** Summary of sampling schedule for each subject

Anatomical Region	Sample type	Sampling times				No. of samples
		First break	Mid-shift break	Last break	End of shift (after washing)	
Palms of both hands	Moist wipes	✓	✓	✓		3
Backs of both hands	Moist wipes	✓	✓	✓		3
Forearm (left and right)	Moist wipes	✓	✓	✓		3
Neck (preferred side)	Moist wipes			✓		1
Face (perioral region)	Moist wipes			✓		1
Chest	Moist wipes			✓		1
Finger nails (all)	Under-nail scrape		✓		✓	2
Head and hair	Moist wipes				✓	1
TOTAL no of samples per subject (excluding blanks)						15

A field blank sample was obtained for each subject sampled. This was done in order to check for contamination introduced during the sampling procedure. The field blanks comprised a series of three wipes which were handled in the same way as the exposed samples but without being wiped over the workers’ skin. The lead content of the field blank was subtracted from the measured values for the corresponding set of samples.

The sample procedure used for collecting the exposure measurements from the zinc/lead refinery workers was slightly different. This work was done in the year 2000, before the current sampling strategy had been developed. In this case the three sets of samples for the hands and forearms were bulked together for each worker, meaning that it was not possible to identify variations in surface skin loading over time. However, the calculated average level

for the hands and forearms is directly comparable with the average hand and forearm measurements collected from these two more recent surveys.

In addition, the face samples obtained during the zinc/lead refinery survey were collected from the forehead rather than the perioral region. Also, no finger nail scrapings were collected and no end-of-shift head wipe samples were obtained. Nevertheless, the same sampling method was used and the same sampling personnel were involved in the survey team.

### 3.3 ANALYSIS

All samples were analysed by inductively coupled plasma atomic emission spectroscopy (ICP/AES) for lead. The samples were analysed at the IOM analytical laboratory, which holds accreditation for the analysis of lead and other metals, by ICP/AES. The documented in-house method, based on OSHA method 121 (OSHA, 1991) is accredited by the United Kingdom Accreditation Service (UKAS) under UKAS accreditation number 0374.

All wipe samples were transferred to the laboratory in 250 ml glass jars. Samples of finger nail scraping were shipped in 100 ml glass jars. The wipes contained in each sample jar were digested in 10% nitric acid containing 1% anti-foaming agent to counter the effects of the detergents contained in the wipes. The acid was added directly to the sample container so that the wipes were completely covered with acid.

The sample jars were transferred onto a hot plate and heated to near boiling point for three hours and then left to cool. The resultant solution was vacuum filtered through a 1µm membrane filter. Each sample was made up to a standard volume of 100ml.

Calibration standards were prepared using known weights of analytical grade reagents and the sample masses were determined with reference to these calibration standards. All sample masses were corrected for blank levels and for analytical and sample recovery efficiency using the results from laboratory blanks, spike samples and recovery test samples. Due to the large number of field samples processed it was necessary to prepare fresh laboratory blanks and spike samples for each day's batch of samples processed.

The quantity of lead in each sample was used to calculate the dermal surface loading for each anatomical area, expressed in terms of mass per unit area ( $\mu\text{g}/\text{cm}^2$ ). All field samples were corrected for field blank levels. In the case of the hands and forearms three samples were collected from each of these areas. The skin surface loading for each sample was calculated and an average of each set of three was also calculated.

Individual measurements were calculated, for each subject, for the hands, forearms, neck, face and chest. In addition, an average value was calculated for the hands and arms combined as this is the relevant metric for comparison with predicted exposures obtained from the EASE model. The average value for the hands and arms combined is weighted to take into account the relative surface areas of the different anatomical areas. The average value is calculated using the mean surface areas for hands ( $840 \text{ cm}^2$ ) and the forearms ( $1140 \text{ cm}^2$ ) (EPA, 1997) as follows:

$$\text{Average value hands \& forearms} = \frac{(\text{hands} \times 840) + (\text{forearms} \times 1140)}{(840 + 1140)} \mu\text{g}/\text{cm}^2$$

## **3.4 METHOD VALIDATION**

### **3.4.1 Compatibility of sample media and quantification of detection limit**

Prior to the field surveys, test samples were analysed to check the compatibility of the wipe samples with the laboratory reagents and analytical equipment. The samples were also analysed to determine the background levels of lead and to establish the limit of detection for the analytical method. Blank levels and limits of detection were quantified for one wipe only and multiples of 3 and 6 wipes. Each test was carried out three times.

### **3.4.2 Analytical recovery**

The analytical recovery was determined by preparing a number of spike samples. The spike levels were selected to correspond to surface contamination levels in the range 0.001 mg/cm<sup>2</sup> to 1.0 mg/cm<sup>2</sup>. Since the normal area of sampling is 25cm<sup>2</sup>, samples of lead oxide were prepared for approximately 0.025mg, 0.25 mg and 2.5 mg.

This was done in two ways. Firstly, spike samples were prepared by adding known amounts of lead onto the surface of the wipes. This was done by weighing out quantities of litharge onto plastic boats. The dust samples were removed from the boats using three consecutive wipes and then placed into a glass beaker. A range of spike masses were chosen in order to cover the various site conditions expected.

It was not possible to accurately weigh out litharge samples of less than 0.3 mg. Low level spike samples were therefore prepared using a 10 µg/ml stock solution prepared using litharge in 10% nitric acid.

The litharge used for these tests was provided by Penox Gmbh and was labelled Litharge L9. According to the technical data sheet which accompanied the sample, the material comprised a minimum of 99.8% lead (II) oxide with maximum metallic lead content of 0.01%.

### **3.4.3 Sampling efficiency**

Tests were carried out to determine the removal efficiency of the sampling method. Previous exposure assessment work with zinc (Hughson and Cherrie 2005) and antimony (Niven, 1993) showed that this method provided an acceptable level of recovery, but this was re-evaluated for lead. This was necessary in order to correct for incomplete removal of the skin contamination layer by the wipe sampling method

This was done by applying pre-weighed quantities of lead oxide onto the surface of a section of chamois leather glued to a plywood panel. This was intended to act as a surrogate for human skin. The samples of litharge were placed onto the section of surrogate skin and spread out across a defined surface area of 100 cm<sup>2</sup> using a spatula. The spatula was wiped repeatedly on the chamois until it was clean. The contaminated surface was then cleaned using three successive wipes. Each wipe was analysed separately in order to evaluate the relative efficiency of each successive wipe. The actual recovery efficiency was calculated based on a ratio of the total mass of lead recovered from the wipes to the mass of lead deposited, taking into account any losses from the sample container, etc.

The spike levels were selected on the lowest practical level that could be weighed out and transferred to the surrogate skin media. The spike levels used were in the range 200 – 2000 µg litharge. Since the area of surrogate skin wiped was 100 cm<sup>2</sup>, this represents surface contamination levels of approximately 2 – 20 µg/cm<sup>2</sup>.

#### **3.4.4 Determination of background dermal lead levels**

Background levels of lead on skin were measured by collecting wipe samples from a number of human volunteers not occupationally exposed to lead. These were used to infer typical background levels for the general population. This was limited to hand and forearm areas only. In this case, ten male volunteers were obtained from IOM personnel.

### **3.5 STATISTICAL METHODS**

The workplace dermal exposure data for each exposure category were summarised in terms of maximum and minimum values, median and the upper 90<sup>th</sup> percentile level using Microsoft Excel 2002. This is the summary data normally required for EU regulatory risk assessments (ECB, 2003). The associations between exposures for different anatomical areas were investigated by calculating the Pearson correlation coefficient using SPSS for Windows version 12.01. In addition, correlations between dermal exposure and inhalable dust concentrations were investigated in the same way. Since the data was log-normally distributed, it was log transformed prior to analysis.

In order to summarise the data properly it was necessary to adjust data values that were below the limit of detection. For samples which were less than the limit of detection, the exposure value was set to a level of half the limit of detection, in accordance with the approach suggested by Rajan-Sithamparanadarajah *et al.*, 2004.

### **3.6 EVALUATION OF TASK-BASED DERMAL EXPOSURES USING THE EASE MODEL**

The various observed tasks in each of the workplaces were categorised in terms of the EASE model, so that the exposure measurements could be compared with the EASE predictions. Information about the working practices and control measures were used as inputs to the EASE model and this provided predicted exposure levels for each category of task. The categorisation was done after consideration of the dermal contact level and pattern of use, and is a matter of professional judgement, assisted by on-line help embedded in the EASE computer program. The categorisation was done by an experienced user (GWH) of the EASE model, before the results of the dermal exposure results were known.



## 4. WORKPLACE DESCRIPTIONS

The following sections describe the observed workplace conditions and working practices for each of the three companies included in this assessment. Also, the various tasks or jobs included for sampling are described, together with any exposure controls used by the workforce. Each task is categorised in terms of the EASE model and the predicted dermal exposures are included to enable comparison with the measured results.

### 4.1 ZINC/LEAD REFINERY

The company at this site processed and refined ore to produce zinc, lead and cadmium metal ingots. The ore, which was principally zinc sulphide, was transferred into the plant by conveyor, sintered and then melted in the blast furnace. Reclaimed zinc residues and pelletised steel plant flue dusts were also incorporated into the sinter feed mix as and when available. The molten zinc was tapped off from holding tanks and then transferred to the refinery where it was purified by distillation in an enclosed system. The technology of simultaneously smelting lead and zinc is common practice due to the co-existence of these metals in many naturally occurring ores. The technology is used in UK, Australia, Zambia, France, Germany, Romania, Japan, Canada, Poland, Sardinia, Macedonia, China and India and the scenario sampled is considered to be consistent with lead production practice at various other lead production facilities in the EU. This site was surveyed in year 2000.

The company had a strict occupational hygiene regime in place, and provided dedicated washing and changing areas, separate clean rest areas and a supply of fresh clean work clothes each day. The workers were included in a health surveillance programme supervised by a medical doctor and regular air monitoring and lead and blood tests were carried out. Filtering facemasks were provided for use in certain areas of the factory and protective gloves were provided, although these were mainly for thermal protection. The RPE provided was a half-mask respirator fitted with twin MSA type A2B2E1K1-P3 (combined gas and high efficiency particulate) filters.

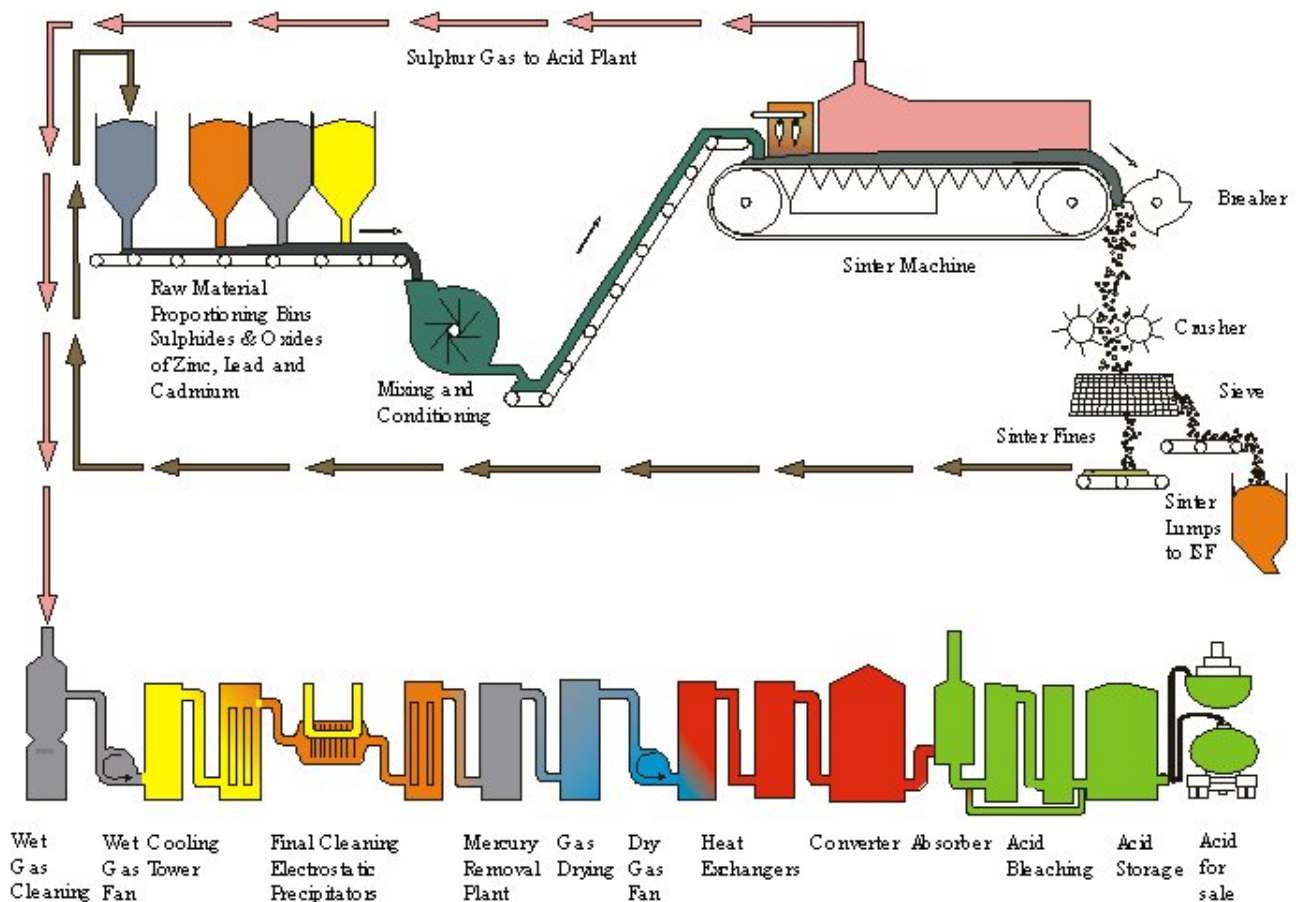
#### 4.1.1 Sinter plant

The purpose of the sinter plant is to remove the sulphur content of the ore and to render it to a composition which can be efficiently processed by the furnace. The raw material was transferred to the sinter plant by conveyors from stockpiles located outdoors. The material was stored in proportioning bins and then transferred to the sinter plant itself where it was roasted and sulphuric acid recovered as a by-product. The resultant sinter was broken up and crushed in an enclosed process and then conveyed to the imperial smelting furnace (ISF). The sinter mix comprised approximately 40% zinc, 20% lead, 11-14% iron and 0.3% cadmium. The remainder consists of calcium, and silicate material. A process diagram of the sinter plant is provided in Figure 1.

There were three to four operators in the raw materials handling area of the sinter plant and all had set routines to inspect and clean blockages from specific conveyor transfer points and crushing machines. Material that built up on the conveyors was cleaned using shovels or other hand tools. However, blockages within machines were more difficult to clear and required the use of compressed air 'lances'. Dust liberated by the use of the compressed air produced gross contamination of work clothing and exposed areas of skin.

The tasks carried out by the majority of the workers in the raw materials and other refinery areas may be categorised in terms of EASE as non-dispersive use with extensive direct

handling. The predicted exposure for this scenario is 1 – 5 mg/cm<sup>2</sup> per day. However, some adjustment is probably required to account for the lead content of the raw materials.



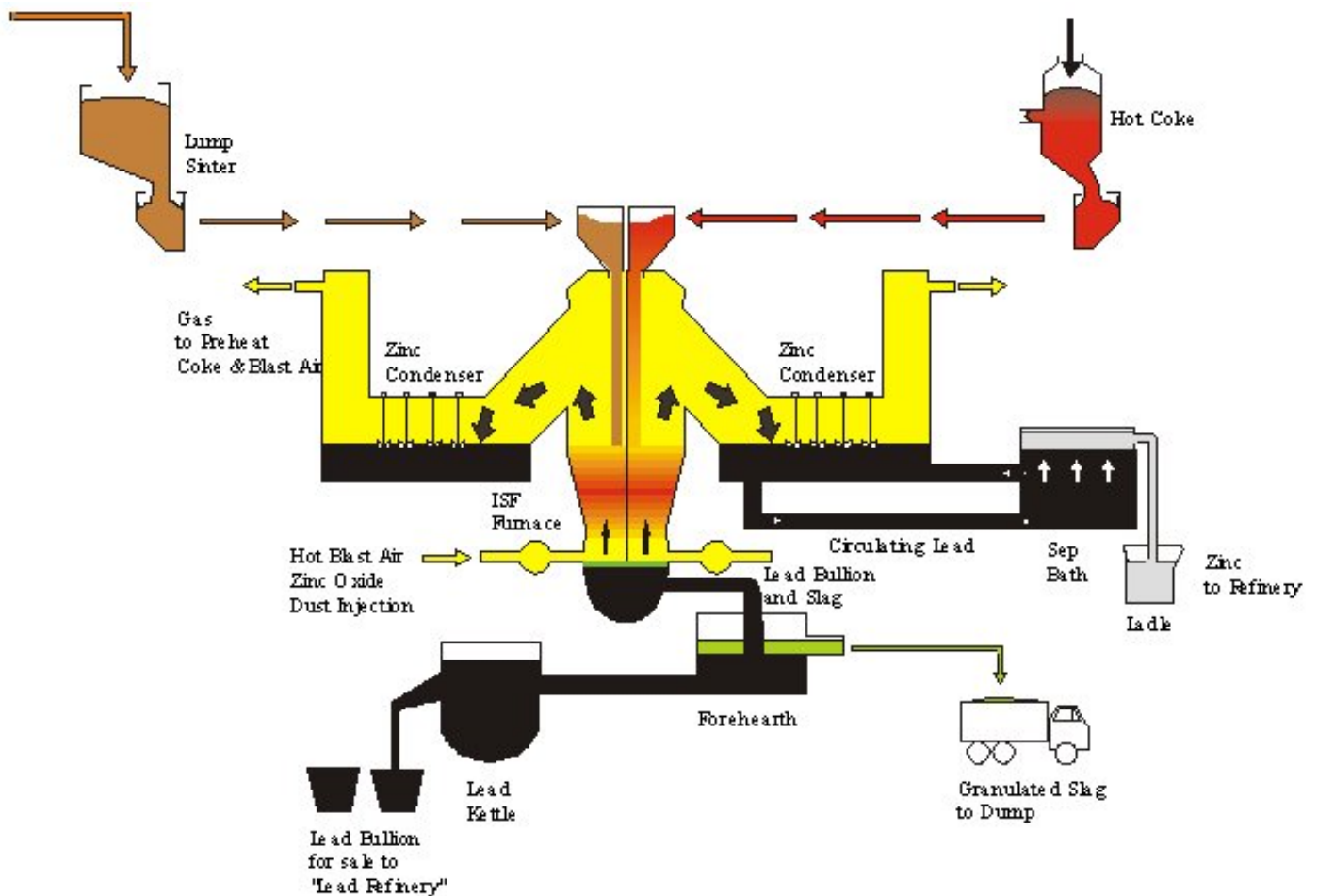
**Figure 1** Schematic of Sinter Plant in Zinc/Lead refinery

#### 4.1.2 Smelting furnace and refinery

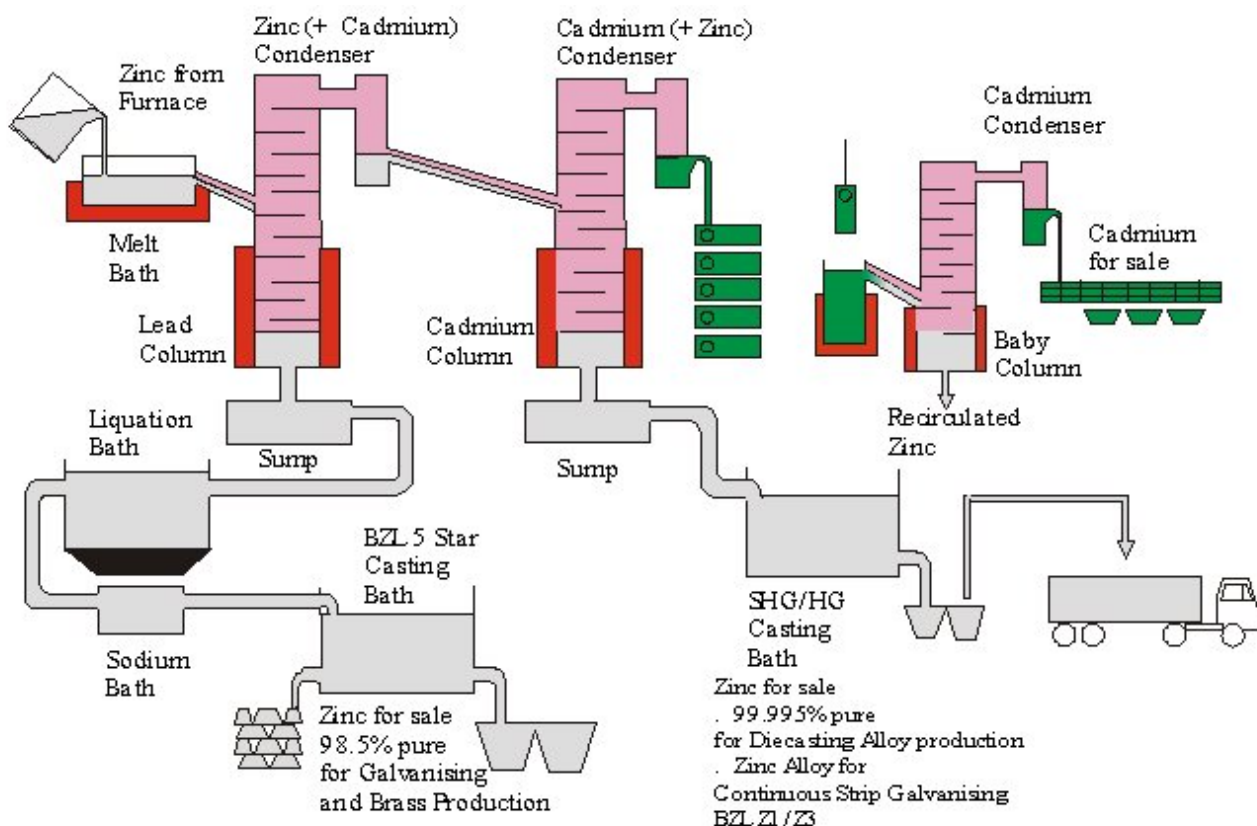
The smelting and refining process is described as follows: Air is blown to the blast furnace shaft at 1000 degrees C and zinc oxide is reduced to zinc metal with evolution of carbon dioxide. Zinc vapour from the furnace passes into the condenser, where fine droplets of lead (created by rotors splashing a pool of molten lead,) dissolve the zinc. Lead from the condenser is pumped through a launder where water-cooled immersion coolers reduce the temperature from 560 to 430 degrees C. The zinc separates from the condenser lead and the zinc is tapped into ladles before being conveyed to the zinc refinery. The lead oxide in sinter feed is reduced to lead in the furnace shaft and is batch tapped from the hearth of the furnace, simultaneously with slag. Lead is recovered together with copper, gold and silver as 4 tonne bullion blocks. The process is illustrated in Figure 2 (ISF) and Figure 3 (refinery).

There were six workers in the furnace areas involved with slagging and drossing operations. This work involved raking-off waste material from the molten metal where it was held in separation baths or at transfer ports and channels. These workers were also involved with cleaning and moving waste materials in skips by forklift truck, and tapping off the molten zinc into ladles for transfer to other areas of the refinery. There were a number of other workers in the refinery involved with the transport and processing of molten metal. These workers were involved in tapping furnaces, transferring ladles of molten metal and preparation of moulds. The workers involved with molten metal work all wore heat protective clothing, which included gloves, during these tasks. The RPE provided for these areas comprised a power assisted filtering visor.

The tasks in these areas could be categorised in terms of EASE as non-dispersive use with intermittent direct contact, because the gloves provided were not kept clean. The predicted exposure for this scenario is 0.1 – 1 mg/cm<sup>2</sup> per day.



**Figure 2** Schematic of imperial smelting furnace (ISF)



**Figure 3** Schematic of zinc/lead refining process

## 4.2 LEAD REFINERY

This company produced lead ingots by smelting and refining lead concentrates and lead scrap. This company had hygiene procedures in place to prevent contamination of personal clothing, and eating and drinking areas. This comprised dedicated washing and showering areas, clean rest zones and a daily supply of clean work clothing. The company also carried out medical surveillance of the workforce, comprising regular lead in blood testing, supervised by a company doctor. This company was surveyed in year 2004.

All workers are provided with clean overalls, safety boots, hard hat, rigger-type gloves and an air assisted filtering visor. The supplied RPE was a Kemira Pro-Flow 2 visor connected to a belt mounted power pack fitted with twin A2B2E2K2P3 filter cartridges. The general gloves used in the plant were Oldenburg CE Cat 2 EN388 rigger gloves.

### 4.2.1 Raw material handling

The raw materials for the smelting process resulted from recycling of lead batteries and other lead products and the concentrates consisted of a wet dross material. The raw materials were unloaded from barges at a jetty area (concentrates) or from railway wagons (lead scrap). This was done using a crane and grab. A small mechanical 'Bobcat' loader was also used in the hold of the ship to scrape up the remainder of the concentrate into piles so that it could be collected by the crane. The material was transferred by means of a conveyor belt system to

open silos within a large storage area and these materials were taken to the blast furnace by mechanical loaders.

There were two to three workers involved with the unloading operations, which occurred approximately once per week depending on production rates. Final manual shovelling of the concentrate was necessary in order to fully recover the concentrates or lead scrap from the ship and wagons. In addition, the conveyor system needed to be kept free of blockages and the workers were involved with routine inspection and clearance of the transfer points. During the course of the monitoring survey one of the conveyor points became badly blocked and there was extensive manual shovelling of the concentrates for a major part of the shift. Since the latter work was not representative of routine operations, the exposures encountered under these conditions may be considered to reflect worst-case conditions.

The raw materials handling work is therefore categorised in terms of EASE as non-dispersive use with extensive direct handling. For these criteria, EASE predicts a dermal exposure level of 1 - 5 mg/cm<sup>2</sup>.

The crane operator for the raw materials area worked inside a ventilated cab and was isolated from the contaminated environment except when leaving the area to check on the work. The task for this job was categorised as non-dispersive use with intermittent direct contact, which has a predicted exposure level of 0.1 – 1 mg/cm<sup>2</sup>.

#### **4.2.2 Smelting**

In this process stage the lead concentrates were reduced in a furnace to lead metal, which was tapped off at the bottom of the furnace in a continuous outflow.

The smelting process was monitored from a remote control room area and there was no manual involvement except during maintenance work. There was one control room operator present in this area and one maintenance worker. The control area was a clean zone, with no requirement to wear protective clothing or RPE. However, the operator was required to don this equipment when leaving the area to carry out inspections.

The potential for exposure occurred mainly at the end of the process, where the slag was removed from the furnace aperture (slagging) and where the molten lead was tapped off into the holding crucibles. The two workers involved with these tasks were provided with thermal protective clothing and wore RPE at all times.

Given that the workers removed their gloves occasionally and could touch contaminated surfaces, the exposure pattern at this workplace is non-dispersive use with intermittent direct contact. For this scenario, EASE predicts a dermal exposure which would be 0.1 – 1.0 mg/cm<sup>2</sup>.

However, three out of the four workers in this area were involved with various maintenance tasks, including cleaning out the air emission control equipment, which left them visibly very dirty. The operators involved in this work were categorised as non-dispersive use with extensive direct contact, with an exposure level of 1.0 – 5.0 mg cm<sup>2</sup>.

#### **4.2.3 Refining and casting**

The molten lead was transported in crucibles by travelling crane to the refinery area where it was treated with sulphur to remove copper and other unwanted metal elements. The purified lead was then cast into ingots using an automatic casting machine.

The raw molten lead arrived at the refinery area in transport vessels, and was transferred to the first reaction vessel. The lead was pumped from one refining stage to the next in a semi-enclosed system. Since the lead was maintained fairly close to its melting point during most of this procedure, potential for exposure was related largely to the various drossing operations. These occurred about once per shift, and when the reaction was complete. The duration of each drossing task was less than one hour, and the amount of waste (i.e., secondary raw material) generated was several hundred kilos.

The molten lead was alloyed with other metals to provide the correct customer specification. This was done by tipping solid ingredients into the holding tanks and stirring with long-handled tools. The molten lead was then fed to an automatic casting machine where robotic arms were used to skim off the molten metal and manipulate the ingots onto the automatic conveyor system.

The use of gloves was required in this area in view of the high temperatures, and the use of RPE was mandatory. There was no direct manual contact with process materials for this operation, although workers would come into contact with contaminated surfaces and contaminated clothing when the gloves were removed.

The exposure pattern at this workplace is non-dispersive use with intermittent direct contact. For this scenario, EASE predicts a dermal exposure of 0.1 – 1.0 mg/cm<sup>2</sup>.

#### **4.2.4 Maintenance**

There were a number of maintenance workers involved with servicing equipment and mobile plant. These workers were included in the sampling survey because they were involved with dusty tasks and had significant potential for exposure. These workers' exposures were variable due to the intermittent direct contact associated with the work. This work is categorised as non-dispersive use with intermittent direct contact, with a predicted exposure level in the range 0.1 – 1.0 mg/cm<sup>2</sup>.

#### **4.2.5 Others**

There were three quality control technicians who were responsible for collecting samples of raw and process materials and were involved with preparation and analysis of these samples. Tasks such as milling and sieving of dust samples were carried out, which resulted in some potential for exposure. This is categorised as non-dispersive use with intermittent direct contact for which EASE predicts an exposure level in the range 0.1 – 1.0 mg/cm<sup>2</sup>.

One additional worker was included in the survey in order to gauge background levels for those not directly involved in production work. This worker was the security/gate controller for the plant. Although this worker was located far off from the main production areas, there was potential for some exposure due to the frequent movement of trucks, which could raise airborne dust, possibly containing residual levels of lead. This work would be categorised as non-dispersive use with no direct contact. The predicted exposure level for this worker is 'very low'.

### **4.3 LEAD CHEMICAL PRODUCTION**

This company produced litharge by thermal oxidation of lead ingots and used this as a feedstock to produce various lead chemicals for end users in the plastic manufacturing sector. This company was surveyed in year 2004.

The site comprised two distinct buildings; the older of these was used for the litharge production and manufacture of bulk lead chemicals. The chemicals produced in this area of the factory were packed into 25 kg paper sacks, 1000 kg capacity flexible IBC (big bags) or in temporary storage bins for transport to various areas around the plant. The second building contained a modern chemical blending plant which was used to prepare and package premixed quantities of lead chemicals and other ingredients in sealed polythene sachets.

The company had implemented a strict hygiene regime. This was intended to prevent workers from moving from lead contaminated zones into clean areas without first undergoing decontamination procedures. Workers were required to remove contaminated work clothing in designated areas and then wash or shower before moving through to the clean areas where clean clothing was provided. All rest breaks were taken in the clean mess areas and eating, drinking or smoking in the general factory areas were prohibited. The workers were provided with clean cotton overalls each day. Mandatory protective equipment included safety boots, hard hats, ear plugs and safety glasses (in certain areas) and RPE was provided in the form of half-mask filtering facepiece respirators (Moldex FFP3D). The RPE was worn continuously by all workers in the production areas, although it was noted that the masks were sometimes pushed down over the face when communicating with each other. Gloves were also worn by the majority of the workforce, and comprised Ansell 'Touch N Tuff' thin nitrile disposable gloves. These gloves were changed frequently over the course of the working shift for reasons of comfort or because they would often split.

#### **4.3.1 Oxide area**

The litharge production area was known as the oxide plant. Here, one operator per shift was involved with loading lead ingots into the two furnaces. The incoming lead ingots were stacked up in the work area and loaded onto the delivery conveyor system using a hoist. This avoided all but incidental contact with the lead ingots.

The plant comprised one Barton pot furnace in which molten lead was held in a heated pot and then metered into the furnace chamber where it was oxidised to form litharge. The Barton pot was a batch process and produced litharge with approximately 3% residual metallic lead content. The second furnace was a rotary furnace, which was a continuous process, producing litharge with approximately 5% metallic lead. The litharge produced by both furnaces was collected in hoppers and fed directly into a series of electric rotary furnaces in order to produce a very high purity litharge, i.e. with <0.01% metallic lead content.

The output from the electric furnaces was collected in a further series of hoppers which discharged into steel IBCs known as 'cones'. These cones were used to transfer the litharge to other areas of the plant.

Gloves were not worn by the operators involved with this task except when there was a risk of contact with hot surfaces. In these cases, thermal protective gloves were used.

Apart from handling the loading equipment for the lead ingots, the operator collected samples of litharge from the various sampling points in the collection hoppers at the rotary furnace, Barton pot furnace and for each of the nine electric furnaces.

The task involved with this process is categorised in terms of EASE as non-dispersive use with intermittent direct handling. For this scenario, the predicted exposure range is 0.1 – 1 mg/cm<sup>2</sup> per day.

### 4.3.2 Vats

Litharge was transferred to the vat areas by forklift truck using the cone containers. Here it was loaded into vats and blended with other substances to produce a variety of lead chemicals including lead phthalate, lead sulphate, lead phosphate and lead stearate. One operator per shift was involved with this process.

The production process was a wet process, using water with sulphuric acid or phosphorous acid depending on the particular formulation required. The cones were discharged into the vats through various loading hatches using a loading gantry and overhead crane for manipulating the cones. The vats were kept under partial negative pressure in order to minimise release of aerosol to the work environment. The operator opened the hatches and tapped the sides of the cone to ensure that all of the litharge was properly discharged. This was done with minimal release of dust into the workplace. The liquid chemicals were fed to the vats via a pipeline system and additional powder ingredients were manually loaded from paper sacks into the vats via a series of loading hatches. This work included loading various non-lead compounds, but some lead chemicals were also loaded in this way, including rework material. Each of the charge hoppers incorporated local exhaust ventilation to minimise emission of dust and vapour to the workplace.

The operator monitored production conditions in each vat and added the various chemicals to each of the vats at the critical times in the process. This meant that there was intensive sack tipping work carried out over the course of the shift and significant potential for dermal contact with lead compounds. At other times the operator was required to carry out visual checks to identify colour changes in the chemicals and he also collected samples of the process liquor for quality control purposes. The operators involved in this particular task always wore the disposable nitrile gloves and half mask respirators.

This task is categorised in terms of EASE as non-dispersive use with extensive direct contact and the predicted exposure level is 1 – 5 mg/cm<sup>2</sup> per day.

### 4.3.3 Dryers

The slurry from the vats was dewatered by centrifuge or by vacuum filtration to remove the solid chemical product from the liquid waste. In the latter case the slurry was passed over a moving filter screen and the suspended particulate captured on the belt dried to form a solid cake. The cake material was automatically removed from the screen and passed into a closed system where it was flash-dried and pulverised into fine powder. This material was discharged to storage hoppers, which then fed to the various packing stations. The materials were packed into big-bags or 25 kg sacks as required. In addition, bulk quantities of the chemicals were loaded into dedicated storage bins for use in the blending plant. Two workers per shift worked in the Dryer area and were occupied with loading and unloading big bags, packing 25 kg sacks using semi-automatic bag fillers, and moving stock containers around the plant on fork lift trucks. The workers in this area wore disposable gloves and the dust respirator, but one of the workers tended not to wear the gloves all the time.

This task is categorised in terms of EASE as non-dispersive use with extensive direct contact and the predicted exposure level is 1 – 5 mg/cm<sup>2</sup> per day.

### 4.3.4 Effluent plant

One worker was involved with supervising the operation of the effluent filtration plant. There should normally be little potential for exposure in this area, but this operator acted as relief operator for other parts of the factory. For example, the operator assisted with packing work

in the Dryer area. Also, part of the work in this area involved manual checking of the effluent filters, which meant that there was potential contact with the cake which formed on the filter press element. At one point during the survey wet filter cake was spilled onto the floor of the factory during disposal to a skip. The operator then had to manually shovel the waste into the skip. This resulted in extensive direct contact with the lead contaminated cake. The worker in this area always wore disposable gloves and a filtering dust respirator.

This task is therefore categorised in terms of EASE as non-dispersive use with extensive direct contact and the predicted exposure level is 1 – 5 mg/cm<sup>2</sup> per day.

#### **4.3.5 Blending plant**

This area, which was known as the Nafto plant, was located in a modern purpose built building. All of the secondary lead chemical materials (lead sulphate, lead stearate, etc..) brought from the main chemical production area were transferred in stock containers which had self-sealing connections designed to fit the blending plant. This helped reduce spillage of powder material into the workplace. Litharge was transferred to the blending plant using mobile storage silos which were linked to loading points located outdoors. One operator was involved with packing blended products into sealed 5 kg capacity polythene sachets. There were approximately two other workers in this building, but they were mainly involved with supervising the process from a remote control room. These latter workers were not included in the sampling survey. One additional worker was included in this category, although he was actually involved with blending in the older building. This was the Gericke operator. In this particular case there was some manual loading of non-lead ingredients, with some packing work too. This operator is included in this category due to the broad similarity of the work involved.

The blending and sachet packing tasks were categorised in terms of EASE as non-dispersive use with intermittent direct handling. For this scenario, the predicted exposure range is 0.1 – 1 mg/cm<sup>2</sup> per day.

#### **4.3.6 Maintenance**

The company retained a permanent contractor for engineering maintenance. This included an electrician and a mechanical engineer/fitter on each shift. These workers needed to dismantle and reassemble lead contaminated plant as part of their normal work and their exposure is categorised in terms of EASE as non-dispersive use with intermittent direct contact. This corresponds to an EASE prediction of 0.1 – 1 mg/cm<sup>2</sup> per day.

An additional worker who was not directly exposed was included in the sampling survey. This was done in order to assess general background contamination levels in a clean area of the plant. In this case, the worker selected was the engineering stores attendant. This particular job did not have any special hygiene procedures associated with it. This task would be categorised in terms of EASE as non-dispersive use with no direct handling and the predicted exposure is 'very low'.



## 5. RESULTS

The results for the method validation and workplace exposure measurements are included in the following sections.

### 5.1 METHOD VALIDATION

#### 5.1.1 Determination of limit of detection and recovery efficiency

Three types of moist wipes were checked to determine their compatibility with the analytical reagents. These were Boots Travel Wipes, Jeyes Family Size Wet Ones and Jeyes 'Sticky Fingers' Wet Ones. All of the types tested were considered to be acceptable on the basis that they did not cause unacceptable foaming when treated with the nitric acid.

Initial spike recovery tests were carried out using preweighed samples of litharge. The results of these tests are detailed in Table 2.

**Table 2** Initial tests of recovery for three different types of moist wipe

Variety of wipe	Spiked mass PbO ( $\mu\text{g}$ )	Mass Pb ( $\mu\text{g}$ )	Actual mass recovered ( $\mu\text{g}$ )	Ratio mass recovered/ true mass	Average for wipe
Boots Travel	80.0	74.280	72.280	0.973	1.073
Boots Travel	10.0	9.285	12.110	1.304	
Boots Travel	40.0	37.140	34.920	0.940	
Wet Ones	18.4	17.084	14.240	0.834	0.774
Wet Ones	20.8	19.313	13.470	0.697	
Wet Ones	21.8	20.241	16.000	0.790	
Sticky Fingers	29.0	26.927	27.490	1.021	0.922
Sticky Fingers	22.6	20.984	19.900	0.948	
Sticky Fingers	24.2	22.470	17.900	0.797	

The Jeyes 'Sticky Fingers' wipes were selected (i) for their convenience of packaging and use in the field, and also (ii) since they showed that the analytical procedure gave an acceptable recovery for the Sticky Fingers wipes with an average value of 0.922.

Additional tests were carried out to determine blank levels for varying numbers of wipes and to establish a detection limit for the analytical method. The results of this procedure are detailed in Table 3.

**Table 3** Blank levels for varying numbers of blank wipe samples

No of wipes	Metal conc (µg/ml)	Vol (ml)	Blank level Pb (µg)	Average for multiple wipes (µg)	SD	LOD
1	0.0265	100	2.650	1.6867	0.970	2.910
1	0.0170	100	1.700			
1	0.0071	100	0.710			
3	0.0168	100	1.680	1.6667	0.240	0.721
3	0.0142	100	1.420			
3	0.0190	100	1.900			
6	0.0243	100	2.430	2.7900	1.512	4.537
6	0.0445	100	4.450			
6	0.0149	100	1.490			
<b>Overall average</b>			2.048			
<b>SD</b>			1.064			
<b>LOD</b>			3.191			
<b>Sample LOD (µg/cm<sup>2</sup>)</b>			0.128			

These results in Table 3 show there was some variability in the blank levels for within the multiple wipe category. If an average of all the samples is taken, then the limit of detection (LOD) for the analytical procedure can be determined using three times the standard deviation (SD), which in this case is equivalent to 3.2 µg. Assuming a sample area of 25 cm<sup>2</sup>, sample LOD is calculated as 0.3 µg/cm<sup>2</sup>.

This experiment was designed to determine the typical blank level for samples comprising varying numbers of these wipes. In practice, when field samples were being analysed separate blank samples were used for each batch of samples being processed. The values for these blanks were subtracted from the measured values for each occupational scenario.

The analytical recovery was tested in more detail using five spike levels. The spike samples were prepared by making a 10 µg/ml stock solution and adding known volumes of solution by pipette onto the wipes. Three wipes were used for each spike sample and the prepared wipes were left overnight to stabilise. The samples were then covered in 10% nitric acid, heated to near boiling point for three hours, cooled, filtered and then analysed by ICP/AES as before. The results of this procedure are detailed in Table 4.

**Table 4** Results of additional spike recovery testing at five different spike level

Spike sample	Spike mass Pb ( $\mu\text{g}$ )	Actual Mass recovered ( $\mu\text{g}$ )	% Recovery efficiency
Sp01	2.386	4.413	185
Sp02	2.386	4.113	172
Sp03	2.386	2.323	97.4
Sp04	9.545	10.84	114
Sp05	9.545	5.106	53.4
Sp06	9.545	4.992	52.3
Sp07	23.86	23.64	99.1
Sp08	23.86	22.20	93.0
Sp09	23.86	21.19	88.8
Sp10	238.6	216.5	90.7
Sp11	238.6	212.3	89.0
Sp12	238.6	218.8	91.7
Sp13	2386	2494	105
Sp14	2386	2462	103
Sp15	2386	2575	108

This analysis showed that there was poor recovery at the lowest spike level of 2.386  $\mu\text{g}$ . The recovery efficiency at the 9.545  $\mu\text{g}$  spike level was in the range 52 – 114%, which is inconsistent within this level. However, the variable recovery efficiency at the lower spike levels is not surprising given the overall blank levels of 2 - 3  $\mu\text{g}$  lead in the wipes used. The recovery efficiency at the 23.86  $\mu\text{g}$  spike level was in the range 89 – 99%, which can be considered to be acceptable. The recoveries at higher spike levels were in the range 89 – 108%, which again can be considered to be acceptable. Considering the spike level of 23.86  $\mu\text{g}$ , the average recovery efficiency at this level is approximately 93.6%. Since the sample area used for exposure measurements is 25  $\text{cm}^2$ , the analytical recovery is reliable for typical dermal exposure of about 1  $\mu\text{g}/\text{cm}^2$ .

### 5.1.2 Determination of sampling efficiency

The sampling efficiency was established by analysing the mass of lead on each wipe used to remove a known mass of lead applied to a surrogate skin media. This was done by applying a known amount of litharge onto separate sections of chamois leather mounted onto plywood board. The sampling efficiency was calculated as the ratio of total recovered lead to the amount deposited. Since it was not possible to weigh out masses of lead powder to less than about 200  $\mu\text{g}$ , the material was spread out over an area of 100  $\text{cm}^2$  in order to simulate low levels of surface contamination, i.e. about 1 – 10  $\mu\text{g}/\text{cm}^2$ .

The results of the recovery tests are detailed in Table 5. These results show that the majority of the lead was removed on application of the first wipe, with small remaining percentages being removed by the second and third wipes. The overall recovery efficiency for lead oxide using this test was 104 % taking into account all measurements. Due to the high level of recovery with this method the field samples were left uncorrected for sampling efficiency.

**Table 5** Results of wipe sampling recovery tests using lead oxide powder

Spike mass Pb (µg)	Wipe sample	Recovered mass Pb each wipe (µg)	Total mass Pb recovered (µg)	% Sampling efficiency per wipe	Overall % sampling efficiency per spike sample
269.21	P1-1	240.87	260.52	89	97
269.21	P1-2	14.46		5	
269.21	P1-3	5.20		2	
235.79	P2-1	285.67	307.21	121	130
235.79	P2-2	14.73		6	
235.79	P2-3	6.82		3	
206.08	P3-1	166.17	193.93	81	94
206.08	P3-2	21.06		10	
206.08	P3-3	6.71		3	
694.37	P4-1	620.27	703.24	89	101
694.37	P4-2	58.12		8	
694.37	P4-3	24.86		4	
766.78	P5-1	752.17	779.33	98	102
766.78	P5-2	18.57		2	
766.78	P5-3	8.60		1	
820.62	P6-1	738.27	817.15	90	100
820.62	P6-2	63.91		8	
820.62	P6-3	14.98		2	
2271.55	P7-1	2344.77	2459.10	103	108
2271.55	P7-2	94.65		4	
2271.55	P7-3	19.69		1	
2384.80	P8-1	2375.77	2549.73	100	107
2384.80	P8-2	127.37		5	
2384.80	P8-3	46.60		2	
2348.60	P9-1	1886.77	2219.01	80	94
2348.60	P9-2	242.67		10	
2348.60	P9-3	89.58		4	
Average Recovery for all samples					104
Minimum					94
Maximum					130

Note: Lead oxide (Penox litharge L9) was weighed in plastic boats and spread out over a 100 cm<sup>2</sup> area of surrogate skin medium. The lead oxide was removed using 3 sequential wipes for each spike sample. Individual wipe samples were digested in 10% nitric acid and analysed for total lead content. The overall sampling efficiency was determined by the ratio of mass of lead recovered to mass of lead deposited onto surrogate skin media.

### 5.1.3 Background dermal lead levels for control group

The results of the background levels of lead on the skin of non-occupationally exposed volunteer subjects are detailed in Table 6. The table contains the results for the analysis of all individual samples for the palms, backs of the hands and the forearms. The surface loadings for each anatomical area are calculated using the sample area for each anatomical area sampled i.e. 50 cm<sup>2</sup>, based on two 25 cm<sup>2</sup> template areas from each limb.

For each subject, the average values for hands, arms and hands and arms combined were calculated.

Out of a total of 30 samples collected, all were below the limit of detection for the method, which was calculated as 0.13 µg/cm<sup>2</sup>.

**Table 6** Background lead levels on skin of non-occupationally exposed volunteers

Subject No.	Surface loading Pb (µg/cm <sup>2</sup> )*				
	Palms	Backs	Average Hands	Forearms	Hands & arms
1	<0.13	<0.13	<0.13	<0.13	<0.13
2	<0.13	<0.13	<0.13	<0.13	<0.13
3	<0.13	<0.13	<0.13	<0.13	<0.13
4	<0.13	<0.13	<0.13	<0.13	<0.13
5	<0.13	<0.13	<0.13	<0.13	<0.13
6	<0.13	<0.13	<0.13	<0.13	<0.13
7	<0.13	<0.13	<0.13	<0.13	<0.13
8	<0.13	<0.13	<0.13	<0.13	<0.13
9	<0.13	<0.13	<0.13	<0.13	<0.13
10	<0.13	<0.13	<0.13	<0.13	<0.13
N	10	10	10	10	10
N<LOD	10	10	10	10	10
Min	---	---	---	---	---
Max	---	---	---	---	---
Median	---	---	---	---	---
90 <sup>th</sup> %	---	---	---	---	---

\*Note – sample loading based on sample surface area of 2 x 25cm<sup>2</sup> = 50 cm<sup>2</sup> areas (both palms, both backs of hands, both forearms)

In view of the results of this procedure it was not appropriate to calculate summary statistics.

## 5.2 RESULTS OF DERMAL SAMPLING IN THE WORKPLACE

A total of 360 individual dermal exposure samples (excluding field blanks) were collected for lead analysis. An additional 86 supplemental samples of residual contamination from the finger nails and head/hair were also collected, making a grand total of 446 field measurements (considering only the surveys carried out in year 2004). Each sample was analysed for elemental lead. There were 32 complete sets of exposure measurements, collected from 32 different workers.

In addition, sample results obtained from the zinc/lead refinery survey in year 2000, which were previously analysed for lead content were reviewed and incorporated into this report.

These results comprised 14 complete sets of dermal exposure measurements from 14 different workers in the main areas within the refinery where dermal lead exposure could occur.

The results of the dermal lead sample analysis for the three workplace surveys are detailed in Tables 7 – 9. The results of the dermal sampling exercise at the zinc/lead refinery from the year 2000 are considered first and are detailed in Table 7. These results are expressed in terms of an average dermal lead skin loading in  $\mu\text{g}/\text{cm}^2$ , for the hands, forearms, hands and arms combined, neck, forehead and chest. Sample results below  $0.1 \mu\text{g}/\text{cm}^2$  are quoted as  $<0.1 \mu\text{g}/\text{cm}^2$ , which is the limit of detection for this method, rounded to one decimal place.

The work activities for each operator sampled are included in Appendix 1 (Tables A1 – A6).

The results of the dermal sampling survey at the lead refinery are detailed in Table 8. This shows the average dermal lead levels in terms of  $\mu\text{g}/\text{cm}^2$  for the hands, forearms, hands and forearms combined, neck, face (perioral region) and the chest.

The results of the dermal sampling survey for the lead chemical production plant are detailed in Table 9. This shows the average dermal lead levels in terms of  $\mu\text{g}/\text{cm}^2$  for the hands, forearms, hands and forearms combined, neck, face (perioral region) and the chest.

The results of the individual samples for the hands and forearms (collected three times across the working shift) are detailed for the lead refinery and lead chemical production factory in Tables 10 – 11. It is not possible to produce a similar breakdown of results for the samples collected from the zinc/lead refinery in 2000 because the (usually three) corresponding wipe samples collected during this time were bulked together for analysis.

The individual sample results for the hands and forearms corresponding to the lead refinery workers in Table 8 are detailed in Table 10. The individual sample results for the hands and forearms, corresponding to the results for the lead chemical plant in Table 9 are detailed in Table 11.

It should be noted that the value for the hands and arms combined is weighted to take into account the relative surface areas of the different anatomical areas. The average value is calculated using the mean surface areas for different anatomical areas (EPA, 1997) as explained in Section 3.3.

All samples are corrected for blank levels, field blanks and for analytical recovery from the sampling media. The results are not corrected for background skin levels, with reference to the control group. The sample results are also left uncorrected for sampling efficiency as this was judged to be sufficiently high on this occasion.

The dermal exposure data for each industry sector are illustrated graphically in a series of box-plots, which accompany the corresponding tabular presentation. Figure 4 illustrates the dermal lead exposures for the zinc/lead refinery workers, Figure 5 illustrates the dermal exposures for the lead refinery workers and Figure 6 relates to the measurements obtained for the lead chemical plant workers.

In these plots, the boxes include data from the lower 5<sup>th</sup> and the upper 95<sup>th</sup> percentiles. Outlying data points are indicated by excursions outside the box. The notch in each of the boxes indicates the position of the median.

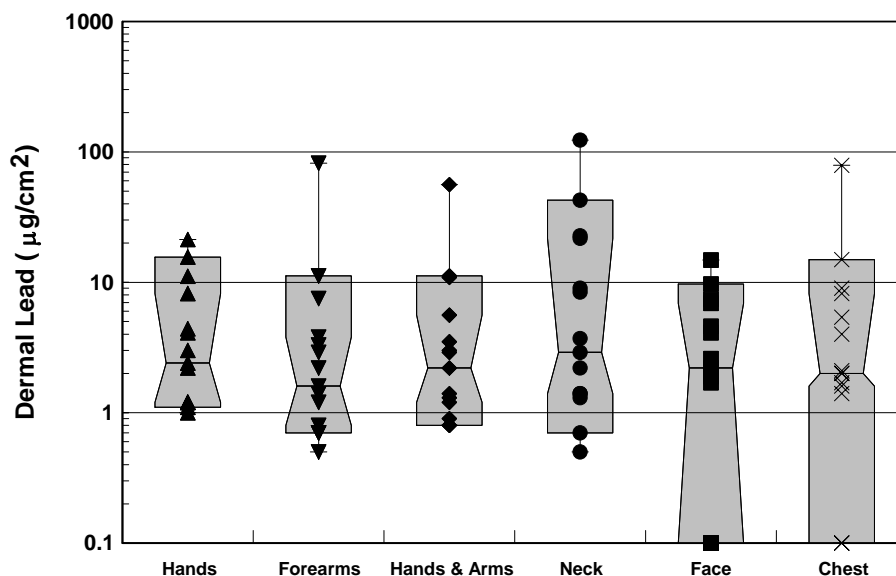
**Table 7** Actual average dermal lead exposures for zinc/lead refinery workers <sup>(Note 1)</sup>

Job description	Dermal lead exposure ( $\mu\text{g}/\text{cm}^2$ )					
	Hands (Note 2)	Forearms (Note 2)	Hands & arms combined	Neck	Forehead	Chest
Sinter plant - P/B op	8.2	3.8	5.6	42.6	7.4	9.0
Sinter plant - Cleaner	11.1	11.2	11.2	22.7	9.7	8.2
Sinter plant - Moisture op	15.6	7.5	10.9	21.7	6.9	4.0
Sinter plant – M/C man	21.3	81.8	56.1	123.0	14.8	78.9
ISF – Condenser 1	2.4	3.3	2.9	1.4	2.6	2.0
ISF – Condenser 2	4.4	2.9	3.5	3.7	4.6	14.9
ISF – Condenser 3	4.1	2.2	3.0	2.2	2.2	1.6
ISF – Slagging 1	3.0	1.6	2.2	9.0	4.1	5.4
ISF – Slagging 2	1.2	0.7	0.9	2.9	0.1	0.1
ISF - Bullion floor	2.2	0.8	1.4	0.7	0.1	2.1
Refinery - Utility op	1.2	0.5	0.8	0.5	1.7	1.4
Refinery - Metal handler 1	1.2	1.2	1.2	1.4	0.1	1.7
Refinery - Metal handler 2	1.1	1.4	1.3	8.4	1.9	2.0
Refinery – Fireman	1.0	0.7	0.8	1.3	0.1	0.1

Notes:

1. Survey carried out in year 2000, before sampling strategy was fully developed. In this case three sets of samples were collected for the hands and arms over the working day. These were bulked together and average exposure levels calculated. This is comparable to the measurements obtained in the later surveys, but individual measurements are not available for each sampling period.

2. Average values of pooled samples

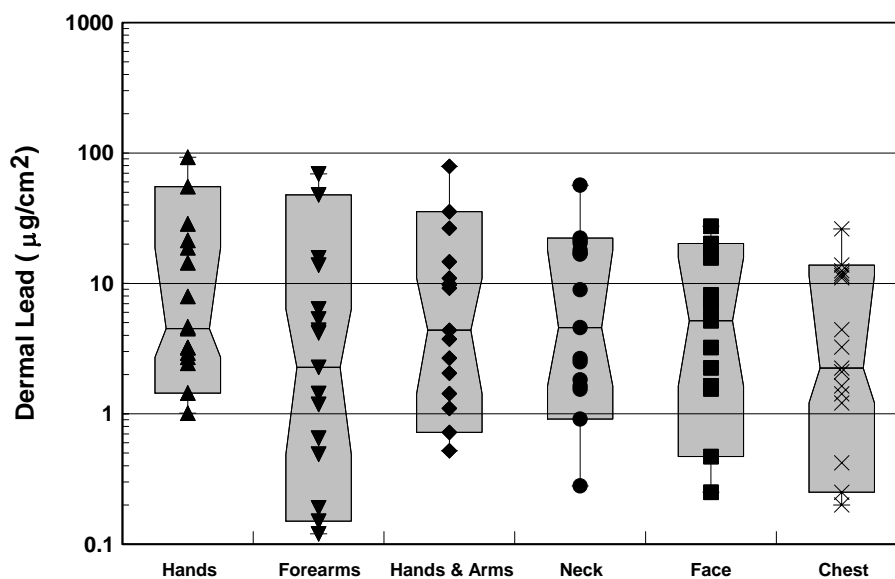


**Figure 4** Dermal lead exposures for zinc/lead refinery workers (all tasks)

**Table 8** Summary of average dermal lead levels for lead refinery workers

Dermal lead exposure ( $\mu\text{g}/\text{cm}^2$ )						
Job	Average Hands (Note)	Average forearms (Note)	Hands & arms combined	Neck	Face	Chest
Raw materials handling 1	18.7	47.8	35.4	22.3	6.4	11.9
Raw materials handling 2	3.2	1.2	2.0	20.3	15.7	11.5
Raw materials handling 3	4.5	15.7	11.0	21.4	8.2	11.0
Raw materials - Craneman	7.9	0.7	3.7	2.6	2.2	1.4
Furnace operator 1	28.6	4.4	14.6	18.0	19.1	12.5
Furnace operator 2	55.2	5.3	26.5	56.6	27.4	26.2
Furnace operator 3	92.6	69.0	79.1	4.6	7.3	4.4
Furnace operator 4	1.5	0.2	0.7	0.3	3.2	0.3
Refinery operator 1	2.7	0.5	1.4	1.5	0.2	2.2
Refinery operator 2	2.4	0.2	1.1	1.6	1.5	1.2
Maintenance – Mechanical 1	21.4	1.5	9.9	16.7	1.6	2.1
Maintenance – Mechanical 2	14.4	6.4	9.8	17.1	16.5	3.2
Maintenance – Mechanical 3	4.6	4.2	4.4	2.5	5.2	1.6
QC Department 1	3.2	2.3	2.7	1.8	0.5	0.4
QC Department 2	1.0	0.2	0.5	0.9	1.6	0.2
QC Department 3	2.9	13.8	9.2	8.9	20.2	13.8
Gate attendant	<0.1	0.6	0.4	<0.1	0.3	<0.1

Note: Average values of three individual exposure measurements collected over working shift

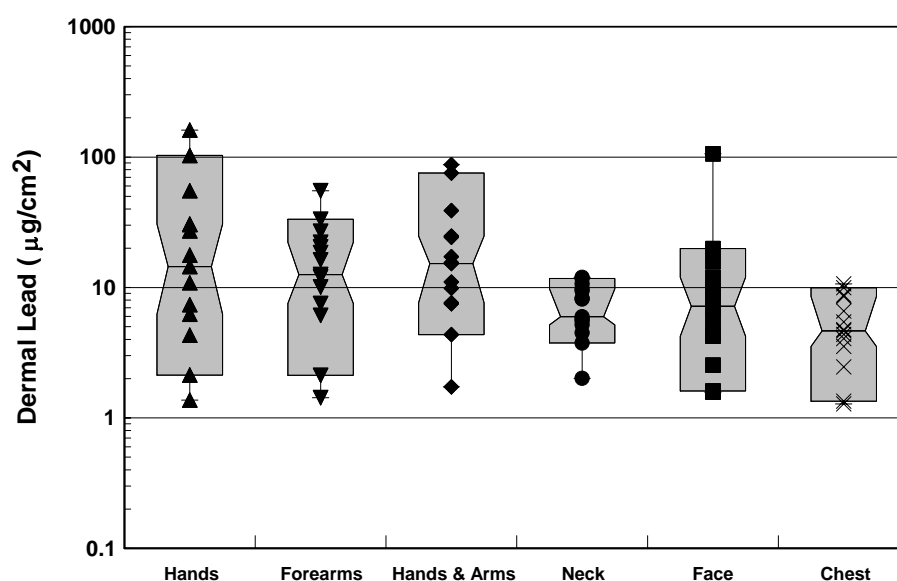


**Figure 5** Dermal lead exposures for lead refinery workers (all tasks)

**Table 9** Summary of average dermal lead levels for lead chemical production plant

Job	Dermal lead exposure ( $\mu\text{g}/\text{cm}^2$ )					
	Average Hands (Note)	Average forearms (Note)	Hands & arms combined	Neck	Face	Chest
Oxide Plant 1	160.9	33.4	87.5	5.5	105.9	4.4
Oxide Plant 2	55.1	26.9	38.9	6.0	8.5	3.5
Vats 1	1.4	12.0	7.5	12.0	9.7	2.5
Vats 2	27.1	22.2	24.3	8.2	12.0	8.7
Driers/packing 1	14.4	16.3	15.5	5.2	4.4	5.4
Driers/packing 2	102.9	55.2	75.4	11.7	19.9	10.7
Driers/packing 3	6.2	12.6	9.9	4.5	2.5	6.6
Effluent Plant 1	30.4	7.5	17.2	9.8	4.2	10.0
Effluent Plant 2	30.6	20.5	24.8	10.7	1.6	4.1
Maintenance - Electrician	17.7	6.1	11.0	8.2	15.8	4.8
Maintenance - Mechanical	7.4	2.1	4.3	5.7	5.8	1.3
Blending/packing (Nafto) 1	4.3	10.1	7.6	9.4	9.7	8.5
Blending/packing (Nafto) 2	10.9	18.5	15.3	3.7	7.2	4.6
Blending/packing (Gericke) 3	2.1	1.4	1.7	2.0	1.6	1.3
Maintenance - Storeman	3.0	0.9	1.8	1.2	3.6	1.1

Note: Average values of three individual exposure measurements collected over working shift



**Figure 6** Dermal lead exposures for lead chemical plant workers

**Table 10** Individual samples results for the hands and forearms, lead refinery

Job	Dermal lead exposure ( $\mu\text{g}/\text{cm}^2$ )							
	Hands				Forearms			
	Sample 1	Sample 2	Sample 3	Average Hands	Sample 1	Sample 2	Sample 3	Average forearms
Raw materials handling 1	27.2	15.6	13.3	18.7	116.8	14.7	11.8	47.8
Raw materials handling 2	5.3	1.9	2.5	3.2	1.6	0.7	1.2	1.2
Raw materials handling 3	N/A	6.3	2.7	4.5	N/A	11.5	19.9	15.7
Raw materials - Craneman	N/A	10.3	5.6	7.9	N/A	0.9	0.5	0.7
Furnace operator 1	3.1	12.0	70.7	28.6	0.8	3.4	8.9	4.4
Furnace operator 2	13.2	110.8	41.4	55.2	2.5	5.9	7.6	5.3
Furnace operator 3	2.2	272.3	3.5	92.6	12.2	190.0	4.9	69.0
Furnace operator 4	N/A	2.8	<0.1	1.5	N/A	0.2	0.2	0.2
Refinery operator 1	N/A	4.5	0.9	2.7	N/A	0.6	0.4	0.5
Refinery operator 2	3.0	1.8	2.5	2.4	<0.1	<0.1	0.2	0.2
Maintenance 1	3.9	53.3	6.9	21.4	<0.1	2.6	1.7	1.5
Maintenance 2	7.4	31.9	3.8	14.4	1.0	16.3	1.8	6.4
Maintenance 3	1.6	6.6	5.7	4.6	3.3	6.2	3.0	4.2
QC Department 1	4.6	2.5	2.5	3.2	3.1	3.3	0.4	2.3
QC Department 2	N/A	0.3	1.8	1.0	N/A	<0.1	0.2	0.2
QC Department 3	N/A	0.3	5.6	2.9	N/A	2.8	24.8	13.8
Gate attendant	<0.1	<0.1	<0.1	0.1	<0.1	1.4	<0.1	0.6
N measurements	11	17	17		11	17	17	
N <LOD	1	1	2		3	2	1	

N/A – Not available (not sampled or rejected)

**Table 11** Individual samples results for the hands and forearms, lead chemical production plant

Job	Dermal lead exposure ( $\mu\text{g}/\text{cm}^2$ )							
	Hands				Forearms			
	Sample 1	Sample 2	Sample 3	Average Hands	Sample 1	Sample 2	Sample 3	Average forearms
Oxide Plant 1	317.4	86.2	79.2	160.9	72.4	12.4	15.4	33.4
Oxide Plant 2	16.4	86.0	63.1	55.1	3.5	58.7	18.6	26.9
Vats 1	0.6	0.6	2.9	1.4	11.5	0.7	23.9	12.0
Vats 2	3.1	N/A	51.2	27.1	5.9	N/A	38.4	22.2
Driers/packing 1	19.6	11.4	12.4	14.4	14.4	13.5	20.9	16.3
Driers/packing 2	141.8	124.2	42.6	102.9	69.0	72.4	24.2	55.2
Driers/packing 3	5.7	9.6	3.4	6.2	10.4	22.9	4.3	12.6
Effluent Plant 1	10.3	72.5	8.3	30.4	4.2	9.2	9.3	7.5
Effluent Plant 2	56.0	4.8	31.1	30.6	14.0	22.5	24.9	20.5
Maintenance - Electrician	4.0	2.1	46.9	17.7	8.4	2.5	7.5	6.1
Maintenance - Mechanical	2.2	7.9	12.0	7.4	1.0	3.0	2.3	2.1
Blending/packing (Nafto) 1	6.4	3.1	3.4	4.3	9.4	7.3	13.5	10.1
Blending/packing (Nafto) 2	11.0	13.4	8.2	10.9	36.7	7.1	11.6	18.5
Blending/packing (Gericke)	2.1	N/A	2.2	2.1	1.6	N/A	1.2	1.4
Maintenance - Storeman	2.4	3.0	3.7	3.0	1.3	0.6	0.9	0.9
N measurements	15	13	15	----	15	13	15	----
N <LOD	0	0	0	----	0	0	0	----

N/A – Not available (not sampled or rejected)

### 5.3 ANALYSIS OF DERMAL EXPOSURE DATA BY INDUSTRY AND EASE CATEGORY

The summary exposure data detailed in Tables 7 – 9 are analysed for each anatomical area sampled by job title/task to determine the number of samples per category (N), the exposure range (minimum and maximum values), median and the upper 90<sup>th</sup> percentile values. These are sorted first by industry (Table 12), then by industry and EASE category (Tables 13 – 15) and then by EASE category for all exposure data (Table 16).

This analysis excludes two sets of measurements, which were not considered to be representative of production tasks; namely the gate attendant for the lead refinery, and the maintenance store man at the lead chemical plant.

All jobs fell within two different EASE task categories. These were non-dispersive use with extensive direct contact or non-dispersive use with intermittent direct contact. The justifications for including the data in the different EASE categories were previously given in the relevant subsections of Section 4.

The data is also illustrated in a series of box plots for the two EASE categories. Figure 7 illustrates the levels for the ‘non-dispersive use – extensive direct contact’ category while Figure 8 relates to the data for the ‘non-dispersive use – intermittent direct contact’ category. An additional diagram is provided in Figure 9, which illustrates the dermal exposure for all workers within the industry, again excluding the two workers not involved in production work.

As stated previously, the box plots include data from the lower 5<sup>th</sup> and the upper 95<sup>th</sup> percentiles. Outlying data points are indicated by excursions outside the box. The notch in each of the boxes indicates the position of the median.

It is clear that all measured exposures were less than the predicted exposure levels given by the EASE model.

**Table 12** Summary of dermal lead exposure data by industry

Industry	N	Dermal lead exposure ( $\mu\text{g}/\text{cm}^2$ )			
		Min	Max	Median	Upper 90%
<b>Zinc/Lead Refinery - all tasks/jobs</b>					
Average Hands	14	1.0	21.3	2.7	14.2
Average Forearms	14	0.5	81.8	1.9	10.1
Hands & Arms	14	0.8	56.1	2.6	11.1
Neck	14	0.5	123.0	3.3	36.6
Face	14	0.1	14.8	2.4	9.0
Chest	14	0.1	78.9	2.1	13.1
<b>Lead Refinery - all tasks/jobs</b>					
Average Hands	16	1.0	92.6	4.6	41.9
Average Forearms	16	0.1	69.0	3.2	31.7
Hands & Arms	16	0.5	79.1	6.8	31.0
Neck	16	0.3	56.6	6.8	21.8
Face	16	0.2	27.4	5.8	19.7
Chest	16	0.2	26.2	2.7	13.1
<b>Lead Chemicals – all tasks/jobs</b>					
Average Hands	14	1.4	160.9	16.1	88.6
Average forearms	14	1.4	55.2	14.4	31.4
Hands & Arms	14	1.7	87.5	15.4	64.5
Neck	14	2.0	12.0	7.1	11.4
Face	14	1.6	105.9	7.8	18.6
Chest	14	1.3	10.7	4.7	9.6

**Table 13** Summary of dermal lead exposure data by industry and allocated EASE task category. (Zinc/lead refinery workers)

EASE category	N	Dermal lead exposure ( $\mu\text{g}/\text{cm}^2$ )			
		Min	Max	Median	Upper 90%
<b><i>Non-dispersive use – extensive direct contact</i></b>					
Average Hands	4	8.2	21.3	13.3	19.6
Average Forearms	4	3.8	81.8	9.4	60.6
Hands & Arms	4	5.6	56.1	11.1	42.7
Neck	4	21.7	123.0	32.6	98.9
Face	4	6.9	14.8	8.5	13.3
Chest	4	4.0	78.9	8.6	57.9
<b><i>Non-dispersive use – intermittent direct contact</i></b>					
Average Hands	10	1.0	4.4	1.7	4.1
Average Forearms	10	0.5	3.3	1.3	2.9
Hands & Arms	10	0.8	3.5	1.3	3.0
Neck	10	0.5	9.0	1.8	8.5
Face	10	0.1	4.6	1.8	4.2
Chest	10	0.1	14.9	1.8	6.4

Note: The predicted exposure level for EASE category of non-dispersive use with extensive direct contact is 1 – 5  $\text{mg}/\text{cm}^2$  per day.

The predicted exposure level for EASE category of non-dispersive use with intermittent direct contact is 0.1 – 1.0  $\text{mg}/\text{cm}^2$  per day.

**Table 14** Summary of dermal lead exposure data by industry and allocated EASE task category. (Lead refinery workers)

EASE Category	N	Dermal lead exposure ( $\mu\text{g}/\text{cm}^2$ )			
		Min	Max	Median	Upper 90%
<b><i>Non-dispersive use – extensive direct contact</i></b>					
Average Hands	6	3.2	92.6	23.7	73.9
Average Forearms	6	1.2	69.0	10.5	58.4
Hands & Arms	6	2.0	79.1	20.6	57.3
Neck	6	4.6	56.6	20.9	39.4
Face	6	6.4	27.4	11.9	23.2
Chest	6	4.4	26.2	11.7	19.3
<b><i>Non-dispersive use – intermittent direct contact</i></b>					
Average Hands	10	1.0	21.4	3.1	15.1
Average Forearms	10	0.1	13.8	1.0	7.1
Hands & Arms	10	0.5	9.9	3.2	9.8
Neck	10	0.3	17.1	2.2	16.8
Face	10	0.2	20.2	1.9	16.9
Chest	10	0.2	13.8	1.5	4.3

Note: The predicted exposure level for EASE category of non-dispersive use with extensive direct contact is 1 – 5  $\text{mg}/\text{cm}^2$  per day.

The predicted exposure level for EASE category of non-dispersive use with intermittent direct contact is 0.1 – 1.0  $\text{mg}/\text{cm}^2$  per day.

**Table 15** Summary of dermal lead exposure data by industry and allocated EASE task category. (Lead chemical workers)

EASE category	N	Dermal lead exposure ( $\mu\text{g}/\text{cm}^2$ )			
		Min	Max	Median	Upper 90%
<b><i>Non-dispersive use - extensive direct contact</i></b>					
Average Hands	7	1.4	102.9	27.1	59.5
Average Forearms	7	7.5	55.2	16.3	35.4
Hands & Arms	7	7.5	75.4	17.2	45.0
Neck	7	4.5	12.0	9.8	11.8
Face	7	1.6	19.9	4.4	15.1
Chest	7	2.5	10.7	6.6	10.2
<b><i>Non-dispersive use - intermittent direct contact</i></b>					
Average Hands	7	2.1	160.9	10.9	97.5
Average Forearms	7	1.4	33.4	10.1	29.5
Hands & Arms	7	1.7	87.5	11.0	58.3
Neck	7	2.0	9.4	5.7	8.7
Face	7	1.6	105.9	8.5	51.8
Chest	7	1.3	8.5	4.4	6.3

Note: The predicted exposure level for EASE category of non-dispersive use with extensive direct contact is 1 – 5  $\text{mg}/\text{cm}^2$  per day.

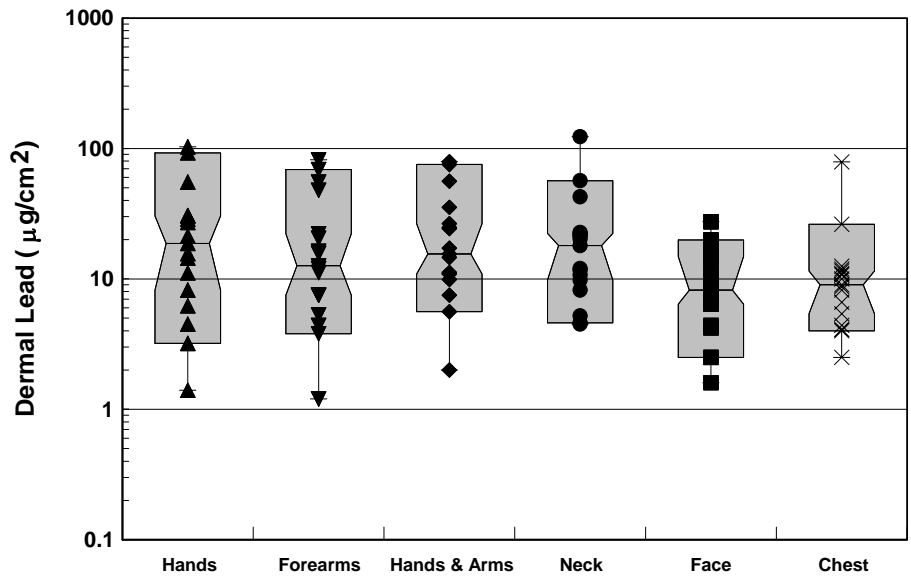
The predicted exposure level for EASE category of non-dispersive use with intermittent direct contact is 0.1 – 1.0  $\text{mg}/\text{cm}^2$  per day.

**Table 16** Summary of dermal lead exposure data by allocated EASE task category. (Zinc/Lead Refinery, Lead Refinery and Lead Chemical workers combined)

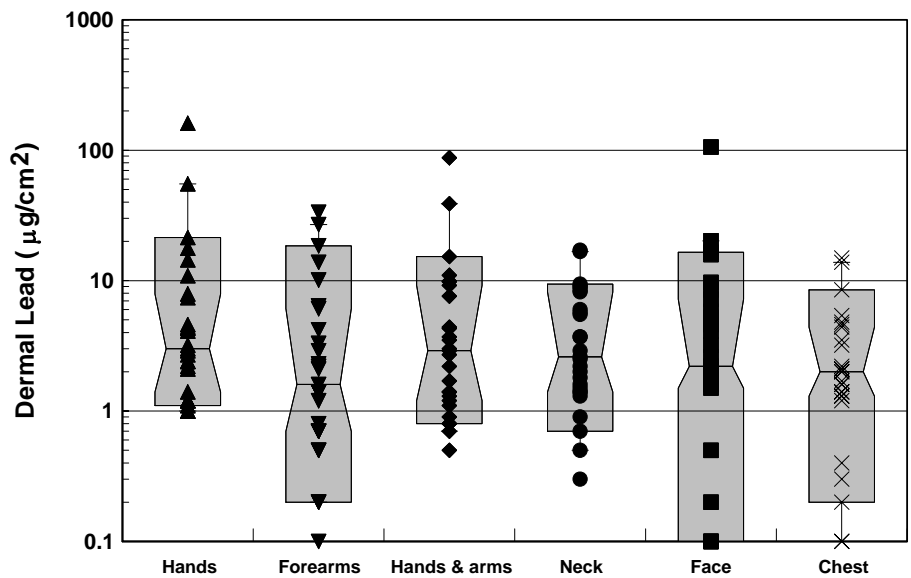
EASE category	N	Dermal lead exposure ( $\mu\text{g}/\text{cm}^2$ )			
		Min	Max	Median	Upper 90%
<b>All tasks/jobs</b>					
Average Hands	44	1.0	160.9	5.4	47.8
Average Forearms	44	0.1	81.8	4.3	31.4
Hands & Arms	44	0.5	87.5	7.6	37.9
Neck	44	0.3	123.0	5.8	22.1
Face	44	0.1	105.9	4.9	18.3
Chest	44	0.1	78.9	4.0	12.3
<b>Non-dispersive use – extensive direct contact</b>					
Average Hands	17	1.4	102.9	18.7	70.1
Average Forearms	17	1.2	81.8	12.6	60.7
Hands & Arms	17	2.0	79.1	15.5	63.9
Neck	17	4.5	123.0	18.0	48.2
Face	17	1.6	27.4	8.2	19.4
Chest	17	2.5	78.9	9.0	18.0
<b>Non-dispersive use – intermittent direct contact</b>					
Average Hands	27	1.0	160.9	3.0	19.2
Average Forearms	27	0.1	33.4	1.6	15.7
Hands & Arms	27	0.5	87.5	2.9	12.7
Neck	27	0.3	17.1	2.6	9.2
Face	27	0.1	105.9	2.2	16.1
Chest	27	0.1	14.9	2.0	6.7

Note: The predicted exposure level for EASE category of non-dispersive use with extensive direct contact is 1 – 5  $\text{mg}/\text{cm}^2$  per day.

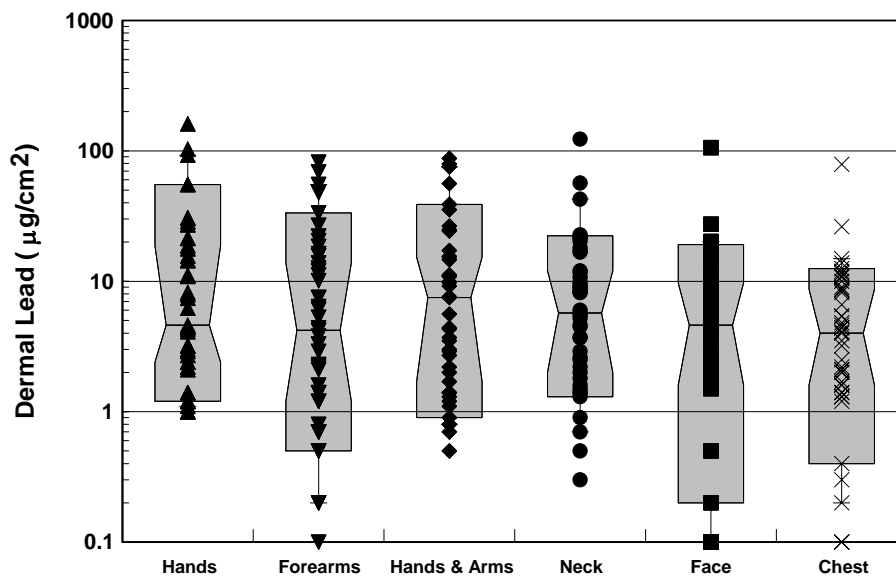
The predicted exposure level for EASE category of non-dispersive use with intermittent direct contact is 0.1 – 1.0  $\text{mg}/\text{cm}^2$  per day.



**Figure 7** Dermal lead exposure in three workplaces by EASE category  
 'Non-dispersive use – extensive direct contact'



**Figure 8** Dermal lead exposure in three workplaces by EASE category  
 'Non-dispersive use – intermittent direct contact'



**Figure 9** Dermal lead exposures

All workers: zinc refinery, lead refinery and lead chemical plant combined

#### 5.4 RESULTS OF RESIDUAL CONTAMINATION FROM HAIR AND FINGER NAILS

The levels of lead recovered from the head (after showering) and finger nails (mid-shift and after showering) are detailed in Tables 17 and 18. Table 17 contains the measured levels of contamination for the lead refinery workers and Table 18 relates to the workers in the lead chemical plant. Corresponding data is not available for the zinc/lead refinery surveyed in year 2000 due to the different sampling strategy adopted as previously explained.

This was a preliminary investigation aimed at determining whether or not there were significant levels of contamination present, and the sampling procedure was pragmatic. The level of contamination recovered in each case is quoted simply as mass of lead in µg. It is not possible to standardise the measurements of finger nail contamination due to the inherent differences in finger nail length between individuals. Similarly, the sample method for the hair and head after showering was not standardised and the results are again quoted simply as the mass of lead recovered from each sample in µg. In order to aid comparison between individuals, the residual contamination data has been presented together with the measured dermal exposures in each case.

**Table 17** Comparison of measured dermal exposures and residual contamination under finger nails and on hair/head after showering. (Lead Refinery Workers)

Job	Dermal Pb surface loading ( $\mu\text{g}/\text{cm}^2$ )				Mass Pb ( $\mu\text{g}$ ) on other areas		
					Finger nail scraping	Hair and head wipe	
	Hands	Neck	Face	Chest	Mid-shift	End of shift (after shower)	End of shift (after shower)
Raw materials handling 1	18.7	22.3	6.4	11.9	64	26	78
Raw materials handling 2	3.2	20.3	15.7	11.5	29	<2	191
Raw materials handling 3	4.5	21.4	8.2	11.0	18	4	119
Raw materials – Craneman	7.9	2.6	2.2	1.4	40	<2	11
Furnace operator 1	28.6	18.0	19.1	12.5	48	3	33
Furnace operator 2	55.2	56.6	27.4	26.2	144	<2	59
Furnace operator 3	92.6	4.6	7.3	4.4	730	<2	20
Furnace operator 4	1.4	0.3	3.2	0.3	70	8	18
Refinery operator 1	2.7	1.5	0.2	2.2	15	4	19
Refinery operator 2	2.4	1.6	1.5	1.2	17	5	204
Maintenance 1	21.4	16.7	1.6	2.1	44	5	12
Maintenance 2	14.4	17.1	16.5	3.2	360	7	34
Maintenance 3	4.6	2.5	5.2	1.6	257	12	23
QC Department 1	3.2	1.8	0.5	0.4	22	<2	28
QC Department 2	1.0	0.9	1.6	0.2	26	<2	20
QC Department 3	2.9	8.9	20.2	13.8	7	5	22
Gate attendant	0.1	0.1	0.3	0.1	8	<2	47

**Table 18** Comparison of measured dermal exposures and residual contamination under finger nails and on hair/head after showering. (Lead Chemical Workers)

Job	Dermal Pb surface loading ( $\mu\text{g}/\text{cm}^2$ )				Mass Pb ( $\mu\text{g}$ ) on other areas		
					Finger nail scraping	Hair and head wipe	
	Hands	Neck	Face	Chest	Mid-shift	End of shift (after shower)	End of shift (after shower)
Oxide Plant 1	160.9	5.5	105.9	4.4	351	40	312
Oxide Plant 2	55.1	6.0	8.5	3.5	204	153	117
Vats 1	1.4	12.0	9.7	2.5	23	6	137
Vats 2	27.1	8.2	12.0	8.7	N/A	88	245
Driers/packing 1	14.4	5.2	4.4	5.4	52	15	63
Driers/packing 2	102.9	11.7	19.9	10.7	704	82	135
Driers/packing 3	6.2	4.5	2.5	6.6	162	41	118
Effluent Plant 1	30.4	9.8	4.2	10.0	112	18	260
Effluent Plant 2	30.6	10.7	1.6	4.1	103	54	90
Maintenance - Electrician	17.7	8.2	15.8	4.8	62	18	176
Maintenance - Mechanical	7.4	5.7	5.8	1.3	113	9	179
Blending/packing (Nafto) 1	4.3	9.4	9.7	8.5	40	13	90
Blending/packing (Nafto) 2	10.9	3.7	7.2	4.6	321	141	16
Blending/packing (Gericke)	2.1	2.0	1.6	1.3	41	<2	48
Maintenance - Storeman	3.0	1.2	3.6	1.1	23	10	83

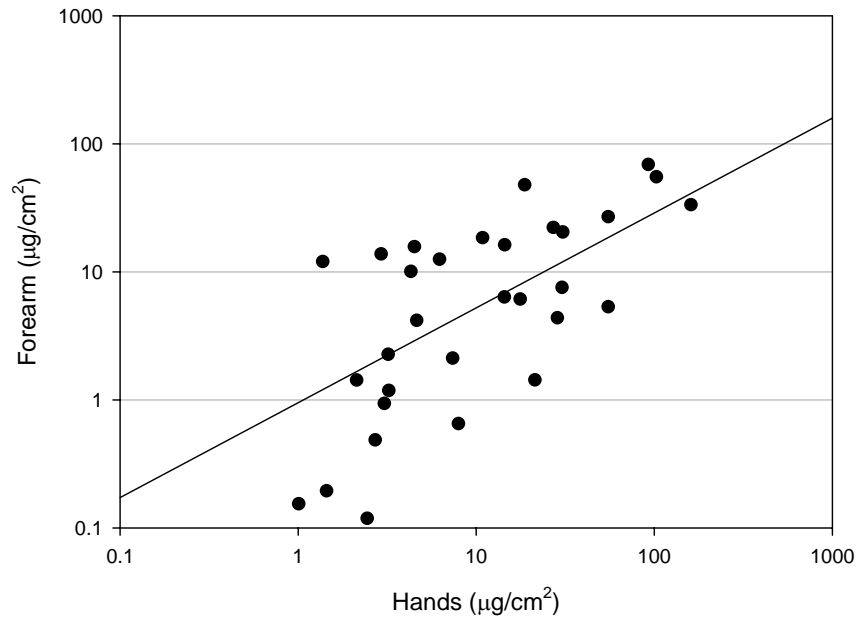
N/A – Not available (not sampled or rejected)

## 5.5 CORRELATION OF EXPOSURE DATA BY ANATOMICAL AREA

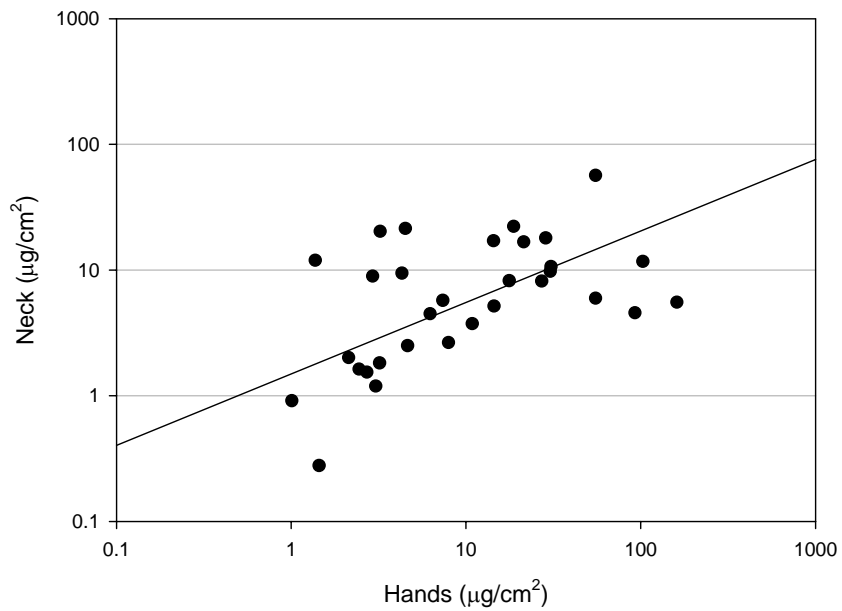
The dermal exposure measurements for each anatomical area (hands, arms, neck, face and chest plus finger nail scrapings and head/hair wipes) were compared with each other to identify any associations.

The exposure data used for this comparison is detailed in Table 19 and the results of the Pearson correlations are detailed in Table 20. The work locations and subjects are identified uniquely as for example; Oxide plant operator 1 and 2 or Furnace operator 1, 2, etc.

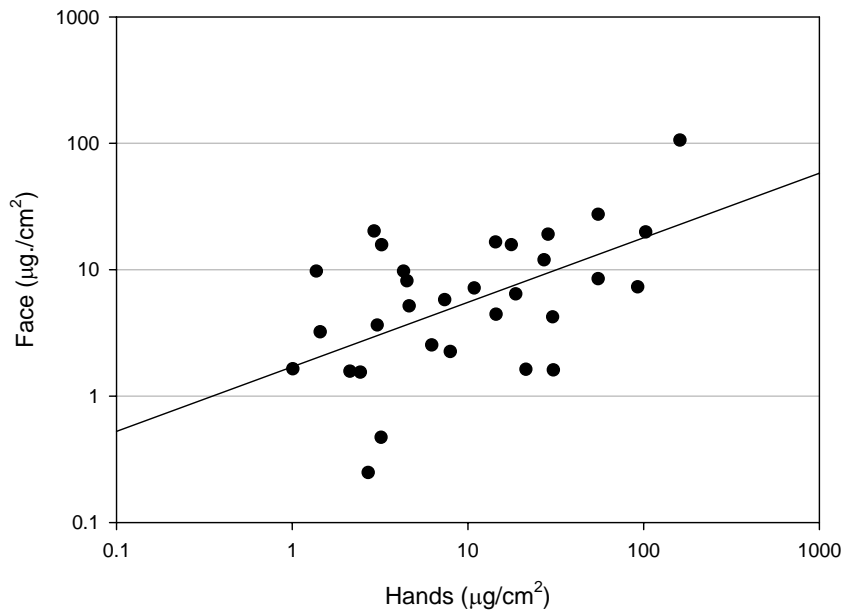
The results of the Pearson correlation tests (Table 20) showed a high level of correlation between the hands and forearms ( $r=0.686$ ), hands and neck ( $r=0.655$ ), hands and face ( $0.605$ ), and between the hands and chest ( $r=0.662$ ). All  $p$  values were highly significant, with  $p < 0.001$ . These comparisons are included as scatter plots, with corresponding lines of regression, as shown in Figures 10 – 13.



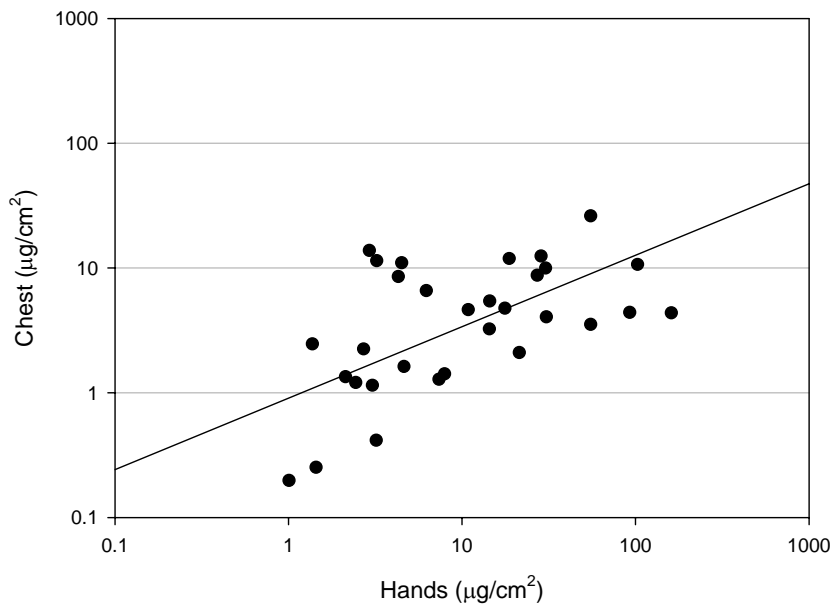
**Figure 10** Comparison of dermal lead exposures: hands and forearms



**Figure 11** Comparison of dermal lead exposures: hands and neck

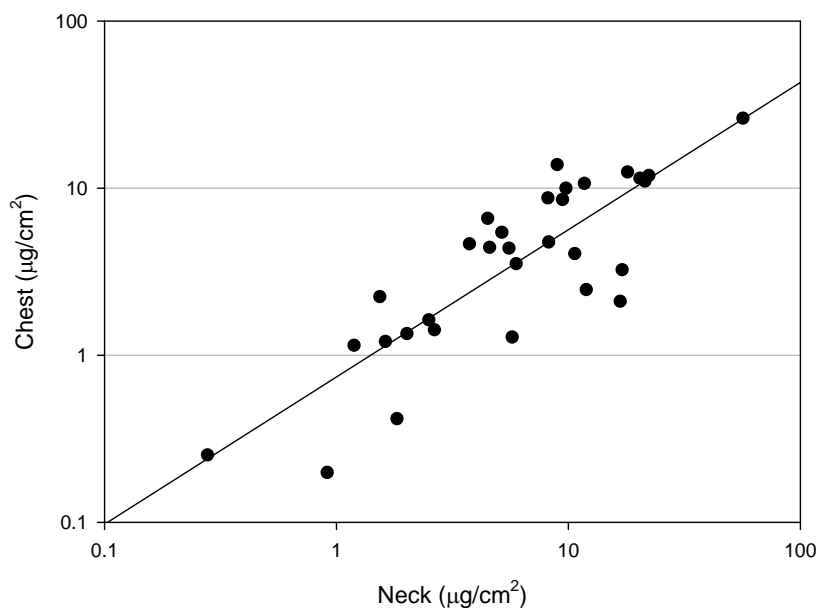


**Figure 12** Comparison of dermal lead exposures: hands and face (perioral region)

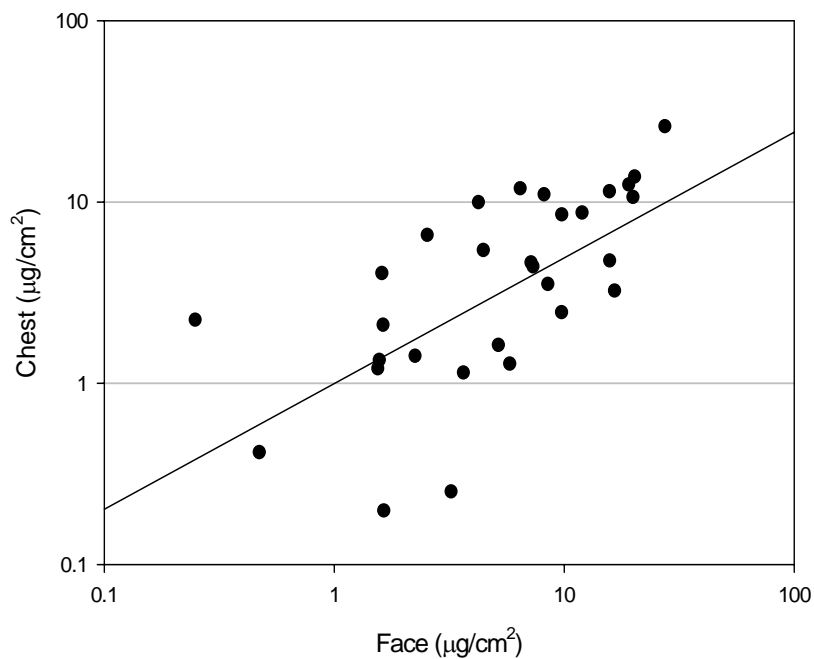


**Figure 13** Comparison of dermal lead exposures: hands and chest

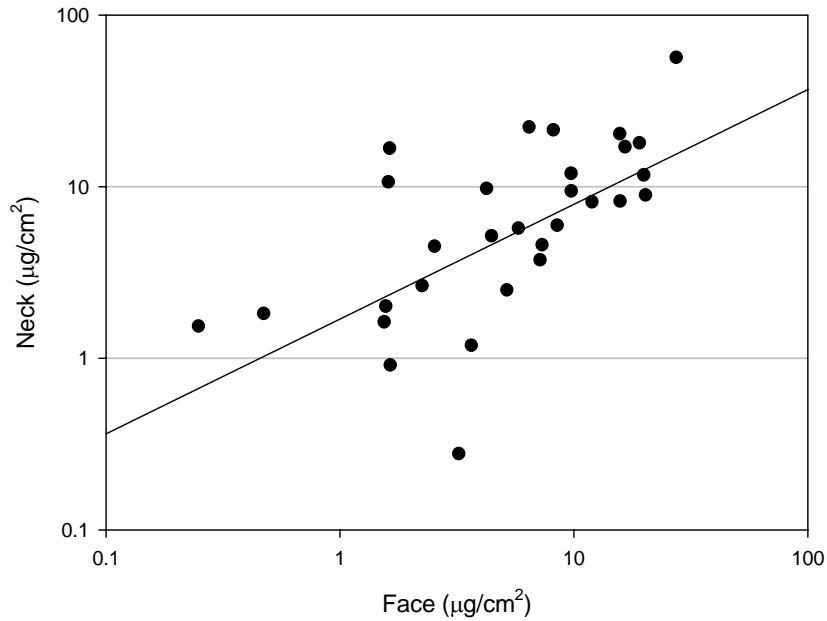
All upper body exposure measurements (neck, face and chest) were highly correlated with each other. The highest correlation was for neck and chest ( $r=0.876$ ), with face and chest next ( $r=0.672$ ) and then face and neck ( $r=0.647$ ). Again, these associations were all highly significant ( $p<0.001$ ). These comparisons are included in scatter plots, with corresponding lines of regression, in Figures 14 -16.



**Figure 14** Comparison of dermal lead exposures: neck and chest

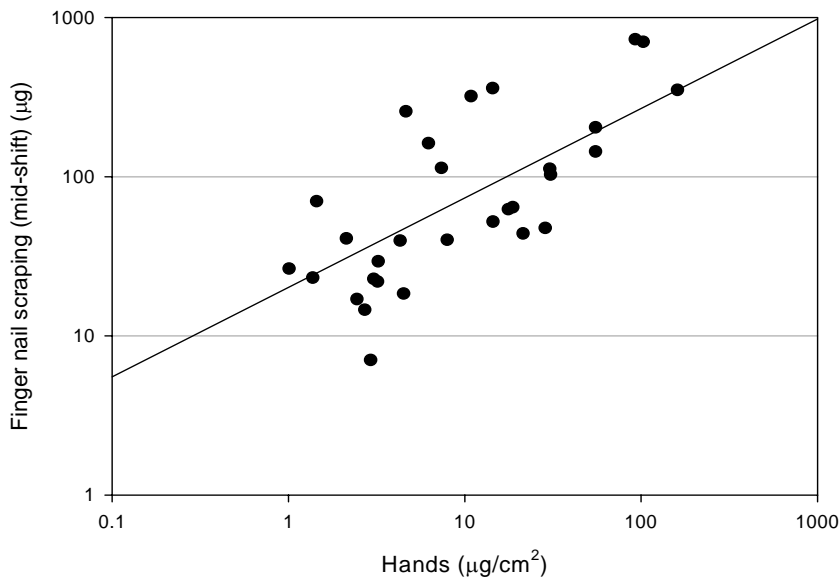


**Figure 15** Comparison of dermal lead exposures: face and chest

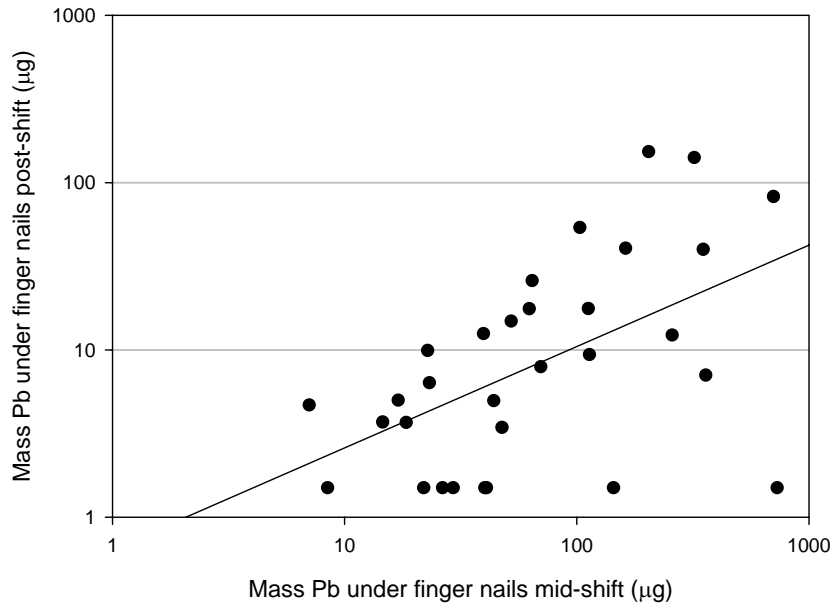


**Figure 16** Comparison of dermal lead exposures: face and neck

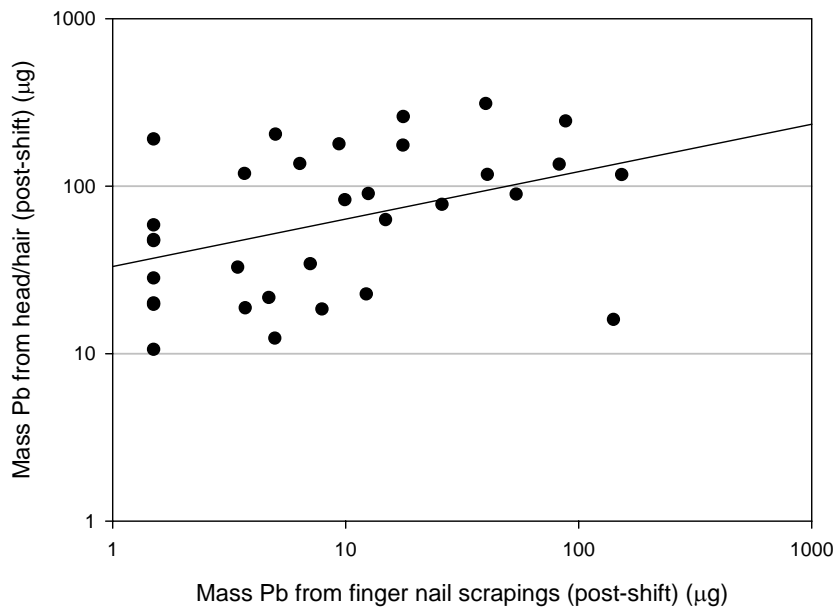
However, when the dermal exposure data were compared with the residual contamination from the finger nail scrapings and head/hair wipes, there were only significant correlations with the dermal hand exposures. The highest correlation for these data were for the hands and mid-shift finger samples ( $r=0.748$ ), with reduced level for the hands and end-of-shift finger nails samples ( $r=0.489$ ). There was also a significant correlation between the mid-shift finger nail samples compared with the end-of-shift finger nail samples ( $r=0.544$ ). There was an indication of some correlation with the end-of-shift head/hair samples compared with the end-of-shift finger nail scrapings ( $r=0.407$ ). These correlations are illustrated graphically for the hands, forearms, neck, face and chest in Figures 17 – 19 respectively.



**Figure 17** Comparison between dermal lead exposures and under-fingernail scrapings



**Figure 18** Comparison between mid-shift and post-shift finder nail scrapings



**Figure 19** Comparison between end of shift residual contamination levels (finger nail scrapings and head/hair wipe samples)

**Table 19** Comparisons of dermal exposure data with residual contamination levels  
(All subjects from lead refinery and lead chemical plant)

Job	Skin surface loading ( $\mu\text{g}/\text{cm}^2$ )					Mass Pb detected ( $\mu\text{g}$ )		
	Hands (avg)	Arms (avg)	Neck	Face	Chest	Nails (mid-shift)	Nails (after wash)	Hair/head (after wash)
<b>Lead refinery</b>								
Raw materials handling 1	18.7	47.8	22.3	6.4	11.9	64	26	78
Raw materials handling 2	3.2	1.2	20.3	15.7	11.5	29	<2	191
Raw materials handling 3	4.5	15.7	21.4	8.2	11.0	18	4	119
Raw materials (Crane)	7.9	0.7	2.6	2.2	1.4	40	<2	11
Furnace operator 1	28.6	4.4	18.0	19.1	12.5	48	3	33
Furnace operator 2	55.2	5.3	56.6	27.4	26.2	144	<2	59
Furnace operator 3	92.6	69.0	4.6	7.3	4.4	730	<2	20
Furnace operator 4	1.4	0.2	0.3	3.2	0.3	70	8	18
Refinery operator 1	2.7	0.5	1.5	0.2	2.2	15	4	19
Refinery operator 2	2.4	0.1	1.6	1.5	1.2	17	5	204
Maintenance – Mechanical 1	21.4	1.4	16.7	1.6	2.1	44	5	12
Maintenance – Mechanical 2	14.4	6.4	17.1	16.5	3.2	360	7	34
Maintenance – Mechanical 3	4.6	4.2	2.5	5.2	1.6	257	12	23
QC Department 1	3.2	2.3	1.8	0.5	0.4	22	<2	28
QC Department 2	1.0	0.2	0.9	1.6	0.2	26	<2	20
QC department 3	2.9	13.8	8.9	20.2	13.8	7	5	22
Gate attendant	0.1	0.5	0.1	0.3	0.1	8	<2	47
<b>Lead Chemical plant</b>								
Oxide Plant operator 1	160.9	33.4	5.5	105.9	4.4	351	40	312
Oxide Plant operator 2	55.1	26.9	6.0	8.5	3.5	204	153	117
Vats operator 1	1.4	12.0	12.0	9.7	2.5	23	6	137
Vats operator 2	27.1	22.2	8.2	12.0	8.7	N/A	88	245
Driers/packing 1	14.4	16.3	5.2	4.4	5.4	52	15	63
Driers/packing 2	102.9	55.2	11.7	19.9	10.7	704	82	135
Driers/packing 3	6.2	12.6	4.5	2.5	6.6	162	41	118
Effluent Plant 1	30.4	7.5	9.8	4.2	10.0	112	18	260
Effluent Plant 2	30.6	20.5	10.7	1.6	4.1	103	54	90
Maintenance - Electrician	17.7	6.1	8.2	15.8	4.8	62	18	176
Maintenance - Mechanical	7.4	2.1	5.7	5.8	1.3	113	9	179
Blending/packing (Nafto) 1	4.3	10.1	9.4	9.7	8.5	40	13	90
Blending/packing (Nafto) 2	10.9	18.5	3.7	7.2	4.6	321	141	16
Blending/packing (Gericke)	2.1	1.4	2.0	1.6	1.3	41	<2	48
Maintenance – Storeman	3.0	0.9	1.2	3.6	1.1	23	10	83

N/A = Not available, not sampled

**Table 20** Correlations between dermal exposures between different anatomical areas. Dermal lead skin loading (hands, neck, face and chest) and mass of lead recovered from the finger nails and head/hair (log-transformed data)

Anatomical area / correlation test		Hands (avg)	Arms (avg)	Neck	Face	Chest	Nails (mid-shift)	Nails (after wash)
<b>Arms (avg)</b>	Pearson correlation (r)	0.686						
	Sig (2-tailed) (p)	<0.001						
	N	32						
<b>Neck</b>	Pearson correlation (r)	0.655	0.611					
	Sig (2-tailed) (p)	<0.001	<0.001					
	N	32	32					
<b>Face</b>	Pearson correlation (r)	0.605	0.587	0.647				
	Sig (2-tailed) (p)	<0.001	<0.001	<0.001				
	N	32	32	32				
<b>Chest</b>	Pearson correlation (r)	0.662	0.691	0.876	0.675			
	Sig (2-tailed) (p)	<0.001	<0.001	<0.001	<0.001			
	N	32	32	32	32			
<b>Nails (mid shift)</b>	Pearson correlation (r)	0.748	0.570	0.305	0.478	0.316		
	Sig (2-tailed) (p)	<0.001	0.001	0.095	0.007	0.083		
	N	31	31	31	31	31		
<b>Nails (after wash)</b>	Pearson correlation (r)	0.489	0.581	0.191	0.323	0.334	0.544	
	Sig (2-tailed) (p)	0.005	<0.001	0.294	0.072	0.061	0.002	
	N	32	32	32	32	32	31	
<b>Hair/head (after wash)</b>	Pearson correlation (r)	0.242	0.297	0.305	0.395	0.357	0.099	0.407
	Sig (2-tailed) (p)	0.182	0.099	0.089	0.025	0.045	0.597	0.021
	N	32	32	32	32	32	31	32



## 6. DISCUSSION

The sampling method used for this study was a removal method using moist wipes to remove surface contamination from the exposed skin, or skin areas beneath protective clothing. As such, the results obtained may be considered to be measurements of the average skin surface loading over the working shift. These average exposures were calculated using the results of three separate measurements for the hands and forearms. This is a relevant metric for risk assessment purposes as the main interest is in relating the average level of lead available for uptake through the skin. While it is recognised that this method has certain limitations including concerns about removal efficiency (Brouwer *et al.*, 2000), this method was validated for lead and the sampling protocol was designed to be comparable with previous work carried out for zinc compounds (Hughson and Cherrie 2005), the data from which has been included in regulatory risk assessments for zinc metal (ECB, 2004), zinc oxide and other zinc compounds. It has therefore been demonstrated that this method is suitable for use for assessing dermal occupational exposure levels to lead and lead compounds.

While average exposures were calculated from the separate samples, the individual sample results are presented separately to provide an indication of variability across the working shift. This means that the exposure data could be used to calculate a cumulative daily exposure, if it can be demonstrated that the lead is completely absorbed through the skin.

The validation of the method showed that there was a low background level of lead in the sampling media and there was good recovery efficiency and an acceptable limit of detection for the analytical technique. There was also good sampling recovery efficiency for solid lead particles. Since there were no work processes in which soluble lead species could be anticipated, this method is considered to be reliable for all tasks monitored.

Additional samples collected from a control group of non-occupationally exposed subjects showed that there were low background levels of lead on the skin, at least for this group of people. In all cases, the dermal lead levels were less than the limit of detection which was  $0.13 \mu\text{g}/\text{cm}^2$ . This provides a useful comparison with the occupationally exposed workers and shows that the dermal lead levels for the lead exposed workers were at most 800 times greater than the control group.

It is clear from the results that lead exposures in the lead and zinc/lead refineries included in this survey were low for most routine jobs. The highest actual dermal exposures were recorded for the maintenance operations carried out in the lead refinery and for lead powder packing operations in the lead chemical plant. In the lead refinery, the highest dermal exposures were associated with repairs to the electrostatic emissions equipment (Furnace operators) and manual shovelling of lead concentrates (raw materials handling) during clearance of blocked conveyor belts. In these cases the hands, arms, face and neck all received significantly more surface contamination in comparison with other task categories included in the study.

Dermal lead levels on the hands of those workers involved in molten metal area or in ancillary operations were generally  $<10 \mu\text{g}/\text{cm}^2$ , with higher levels encountered during the upset conditions previously referred to. In these latter cases, average dermal lead exposures for the hands were generally within the range  $10 - 200 \mu\text{g}/\text{cm}^2$ . The observed pattern of exposure would be expected given the relatively mobile nature of the lead powder products and lead-concentrate dusts.

There was some variability in dermal exposure levels within task categories, but probably less than would be expected taking into account the measured data from the zinc industry. This is probably due to the more systematic use of protective clothing and other occupational hygiene control measures in the lead industry. It is also likely that the engineering controls present in the lead chemical plant are key factors in reducing the potential for skin contact. These various factors are reflective of the greater inhalation hazard from lead exposure.

The various tasks identified in this study could be grouped into two different exposure scenarios as defined by the EASE model. These would be categorised as either non-dispersive use with extensive direct handling (e.g. shovelling lead concentrates, powder packing, etc.) and non-dispersive use with intermittent direct handling (e.g. lead oxide operator, blending plant operator, etc.) When the measurements are compared with the EASE predictions for these categories (1 – 5 mg/cm<sup>2</sup> and 0.1 – 1 mg/cm<sup>2</sup> respectively), it is clear that the predicted exposures are higher than the measured levels, by a factor of about 1000 if one compares the upper range EASE value with the upper 95<sup>th</sup> percentile value for the hands in each case. However, the predicted exposure levels produced by EASE are intended to be estimates of potential exposure and do not therefore take into account the attenuating effect of gloves and other protective clothing. Nevertheless, one would not expect gloves or other standard work wear to provide such a high level of protection (Brouwer *et al.*, 2001). This indicates that EASE tends to over-estimate exposure for these workplace scenarios, which is in line with previous evaluations of the EASE model (Creely *et al.*, 2005, Hughson and Cherrie 2005). However, it should be noted that the observed jobs are not easily categorised according to the EASE criteria and other users may select different options for the same workplace and thereby produce different estimates. This highlights other weakness in the EASE model, i.e., that it is not always possible to consistently categorise real-world tasks according to the EASE criteria.

The high level of correlation between dermal exposures to the hands, arms, face, neck and chest is interesting and corresponds with the results of other dermal exposure research (Vermeulen *et al.*, 2000). This high level of correlation is useful when designing future sampling protocols, as it may be possible to extrapolate exposure levels for the main anatomical areas from a relatively limited number of actual exposure measurements.

Other researchers have noted that biological indicators of lead exposure and other metals such as nickel and chromium are poorly correlated to airborne exposures ((Deubner *et al.*, 2001, Far *et al.*, 1993, Karita *et al.*, 1997, Kiilunen *et al.*, 1997). This may be due to inadvertent ingestion of lead and lead compounds, e.g. by licking the lips, by habitual hand-to mouth contact or by smoking or eating with contaminated hands. Indeed, the results from this survey show that there is significant lead contamination in the perioral area, which means that lead ingestion could be a factor in determining systemic uptake in the workplaces included in this survey.

Finally, the results show that there were measurable levels of lead contamination on the head and hair of workers after washing post-shift, i.e. before going home. Furthermore, there were measurable deposits of lead found in scrapings from the finger nails. The significance of these results is unclear, because it is not possible to standardise the measurements between or within individuals and there may well be inherent variability due to inconsistencies in the sampling method. These measurements were simply intended to provide an indication of possible take-home contamination but are nevertheless useful for informing on the effectiveness of hygiene procedures. Given that there were lead deposits detected in the hair samples after washing, these may possibly be available for uptake in the domestic environment, either by the worker or family members. This could occur either by ingestion or by inhalation if the dust becomes airborne. Interpretation of lead contamination in finger nail

scrapings is difficult due to individual and behavioural factors such as nail length and the tendency of the subject to bite the finger nails. Longer finger nails will have the potential to gather more lead contamination, but this is not necessarily available for ingestion since people with longer finger nails, will not tend to be nail-biters. Conversely, the quantity of lead contamination recovered from short finger nails is probably not a good indicator of exposure since the individual may be a frequent nail-biter and has therefore reduced the capacity of the finger nails to gather contamination. This area requires further work to understand the various mechanisms driving exposure and to determine the significance of take-home contamination and the potential for exposure by the ingestion route.



## 7. CONCLUSIONS

A monitoring programme to assess dermal lead exposures was carried out for three different European workplaces. This included a lead/zinc refinery, which recovered lead, zinc and other metals from naturally occurring ores and recycled materials, a lead refinery which recovered lead from scrap and recycled lead concentrates, and a lead chemical manufacturing company producing litharge and lead powder products. A total of 44 sets of dermal exposure measurements were collected from 44 different workers. In most cases, the production and activity levels within each workplace were considered to be typical of normal production, although there were examples of worst case exposures in the lead refinery during manual shovelling of lead concentrates.

The survey programme used a removal method for dermal sampling, with proven reliability. However, it is not possible to state with confidence how much lead was bound to or absorbed through the skin prior to sampling, although dermal uptake of inorganic lead is generally considered to be very low. In this respect, measures of systemic uptake from biological monitoring are invaluable in assessing systemic risks to health.

Overall, the dermal exposures were low, and certainly very much less than predicted values generated by the EASE model. In addition, the dermal lead exposure levels were much lower in magnitude than dermal exposures obtained in the zinc industry. It is concluded that this is largely due to higher levels of engineering controls applied to the lead production processes generally, combined with specific hygiene measures such as the consistent use of personal protective equipment.

Nevertheless there were measurable lead deposits on the hands, arms, face, neck and chest areas of all production workers monitored and there was a high degree of correlation between the different anatomical areas.

The pattern of dermal lead deposition combined with observed working practices shows that there is potential for inadvertent ingestion of lead and lead compounds, either through hand to mouth contact or from deposition into or around the perioral region. The significance of this route of exposure needs to be investigated in more detail. Furthermore, significant levels of lead contamination were identified on workers' heads and hair and under finger nails. This contamination is liable to be taken home and possibly ingested or inhaled after re-suspension into the air, thus increasing potential for exposure of the workers themselves or family members. This indicates there is a need to look in detail at hygiene procedures and identify where improvements can be made.



## 8. STATEMENT OF QUALITY

IOM recognise and adopt accepted UK guidelines for good survey practice

This project was carried out under the IOM project management system, which includes preparation of a written protocol for the research and periodic auditing of the work by experienced senior scientists not actively involved in the study.

IOM has UKAS accreditation for several measurement techniques. While the laboratory analysis of all samples collected under this study is covered by the UKAS accreditation, the sampling protocol is a non-standard research procedure and cannot easily be accredited. However, the sampling procedures followed the general quality procedures required by the overall quality management system. Sampling and analytical quality assurance included appropriate calibration checks, replicate analyses and blank samples

Data processing and reporting was subject to the internal data processing control procedures. Raw data is stored for five years and can be audited by the sponsor.



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## 10. REFERENCES

- Control of Lead at Work Regulations 2002. Statutory Instrument 2002 No. 2676. Norwich: The Stationery Office.
- Bress WC, Bidanset JH. (1991). Percutaneous in vivo and in vitro absorption of lead. *Veterinary and Human Toxicology*; 33: 212-214.
- Brouwer DH, Boeniger MF, van Hemmen J. (2000). Hand wash and manual skin wipes. *The Annals of Occupational Hygiene*; 44: 501-510.
- Brouwer DH, Marquart H, van Hemmen JJ. (2001). Proposal for an approach with default values for the protection offered by PPE, under European new or existing substance regulations. *The Annals of Occupational Hygiene*; 45: 543-553.
- CEC. (1993). Council Regulation (EEC) No. 793/93 of March 1993 on the evaluation and control of the risks of existing substances. *CEC Official Journal*; L084: P0001-P0075.
- Creely KS, Tickner J, Soutar AJ, Hughson GW, Pryde DE, Warren ND, Rae R, Money C, Philips A, Cherrie JW. Evaluation and further development of EASE version 2. *Annals of Occupational Hygiene*. December 13, 2004 (epub ahead of print).
- Deubner DC, Lowney YW, Paustenbach DJ, Warmerdam J. (2001). Contribution of incidental exposure pathways to total beryllium exposures. *Applied Occupational and Environmental Hygiene*; 16: 568-578.
- ECB. (2004). European Union risk assessment report: zinc metal. European Chemicals Bureau, European Commission. (EUR 2269EN). (Human Health No.42).
- ECB. (2003). Technical guidance document on risk assessment. Part 1. Ispra: European Chemicals Bureau, European Commission.
- EPA. (1997). Exposure factors handbook. Washington: Office of Research and Development, National Center for Environmental Assessment, U.S. Environmental Protection Agency. (EPA/600/P-95/002Fa).
- Far HS, Pin NT, Kong CY, Fong KS, Kian CW, Yan CK. (1993). An evaluation of the significance of mouth and hand contamination for lead absorption in lead-acid battery workers. *International Archives of Occupational and Environmental Health*; 64: 439-443.
- HSE. (1996). The assessment of workplace exposure to substances hazardous to health. The EASE Model. Version 2 for Windows (The EASE Manual). Bootle: Health and Safety Executive.
- Hughson GW, Cherrie JW. (2005). (in press). Comparison of measured dermal dust exposures with predicted exposures given by the EASE expert system. *Annals of Occupational Hygiene*.
- Karita K, Shinozaki T, Tomita K, Yano E. (1997). Possible oral lead intake via contaminated facial skin. *The Science of the Total Environment*; 199: 125-131.

Kiilunen M, Utela J, Rantanen T, Norppa H, Tossavainen A, Koponen M, Paakkulainen H, Aitio A. (1997). Exposure to soluble nickel in electrolytic nickel refining. *The Annals of Occupational Hygiene*; 41: 167-188.

Kromhout H, Fransman W, Vermeulen R, Roff M, van Hemmen JJ. (2004). Variability of task-based dermal exposure measurements from a variety of workplaces. *The Annals of Occupational Hygiene*; 48: 187-196.

Niven, KJM. (1993). The development of a method to assess the contamination of skin by antimony in the furniture upholstery industry. MSc Thesis. University of Aberdeen.

OSHA. (1991). Metal and metalloid particulates in workplace atmospheres. OSHA Method ID121. Washington: Occupational Safety and Health Administration, US Department of Labor.

Rajan-Sithamparanadarajah R, Roff M, Delgado P, Eriksson K, Fransman W, Gijssbers JH, Hughson G, Makinen M, van Hemmen JJ. (2004). Patterns of dermal exposure to hazardous substances in European union workplaces. *The Annals of Occupational Hygiene*; 48: 285-297.

Stauber JL, Florence TM, Gulson BL, Dale LS. (1994). Percutaneous absorption of inorganic lead compounds. *The Science of the Total Environment*; 145: 55-70.

Vermeulen R, Heideman J, Bos RP, Kromhout H. (2000). Identification of dermal exposure pathways in the rubber manufacturing industry. *The Annals of Occupational Hygiene*; 44: 533-541.

Watson SI. (1998). An investigation into the role of thermal factors on lead absorption and excretion. MSc Thesis. University of Newcastle-upon-Tyne. Department of Environmental and Occupational Medicine.

## APPENDIX 1 JOB ACTIVITY RECORDS

**Table A1** Job activity record Zinc/Lead refinery - Sinter plant

<b>Job/task description</b>	<b>Sample interval</b>	<b>Activity prior to sampling</b>
Proportioning plant operator (P/B op)	1	Routine checking of conveyors and transfer chutes - cleaning if blocked
	2	Routine checking of conveyors and transfer chutes - cleaning if blocked
	3	Routine checking of conveyors and transfer chutes - cleaning if blocked
Relief operator (cleaner)	1	Cleaning around conveyors, sweeping and shovelling dust
	2	Cleaning around conveyors, sweeping and shovelling dust
	3	Washing down area with hose
Moisture operator	1	Routine checks on enclosed process, sampling and cleaning
	2	Routine checks on enclosed process, sampling and cleaning
	3	Routine checks on process, machine stopped, took moisture off, restarted process
Sinter machine operator (M/C man)	1	Routine checks of machine conveyors and ducts, cleaning with air lance
	2	Routine checks of machine conveyors and ducts, cleaning with air lance
	3	Routine checks of machine conveyors and ducts, cleaning with air lance

**Table A2** Job activity record Zinc/Lead refinery – ISF Furnace and refinery area

<b>Job/task description</b>	<b>Sample interval</b>	<b>Activity prior to sampling</b>
Condenser operator 1	1	Filling flux bell, forklift driving, tipping out bins
	2	Drossing, tapping into ladle, cleaning around launders
	3	Drossing, tapping into ladle, cleaning around launders
Condenser operator 2	1	Filling flux bell, driving fork lift truck, manual shovelling of residues into skip
	2	Drossing melt baths
	3	Drossing melt baths
Condenser operator 3	1	Drossing, tapping, clearing blockages
	2	Tapping into ladle
	3	Tapping, drossing
Slagging operator 1	1	Slagging - Removing slag from molten metal channels, clearing blockages
	2	Slagging, clearing blockages, driving fork lift truck
	3	Slagging, clearing blockages, driving fork lift truck
Slagging operator 2	1	Slagging, clearing blockages
	2	Slagging, clearing blockages
	3	Slagging, clearing blockages
Bullion operator	1	Removing blocks from moulds, driving fork lift truck and operating power press
	2	Removing blocks from moulds, driving fork lift truck and operating power press
	3	Removing blocks from moulds, driving fork lift truck and operating power press
Utility operator	1	Drossing metal baths, driving fork lift truck, collecting/analying samples
	2	Fork lift truck driving, sampling, cast 8 blocks,
	3	Watching furnaces,
Metal handler 1	1	Tapping in furnace area, transferring material to refinery
	2	Drossing melt baths, preparation of moulds and casting blocks
	3	Tapping, pulling blocks, casting blocks
Metal handler 2	1	Drossing off melt baths, pouring ladles,
	2	Pouring ladles, casting blocks, cleaning spillages with brush and shovel
	3	Pouring ladles, casting blocks, cleaning spillages with brush and shovel
Fire man	1	Watching columns, taking strips off, ladle off
	2	Removing strips, ladle off metal, cleaning around columns with sweeping brush
	3	Removing strips, ladle off metal, cleaning around columns

**Table A3** Job activity record Lead Refinery – Raw materials and furnace area

Job title – Subject code	Sample interval	Activity prior to sampling
Raw materials operator 1	1	Unloading crane using crane and shovelling concentrate. Cleaning blockage around conveyor belt
	2	Shovelling concentrate. Driving bobcat in ship hold
	3	Shovelling concentrate. Driving bobcat in ship hold
Raw materials operator 2	1	Shovelling and clearing blockages of lead concentrate from conveyor belt system
	2	Unloading shredded battery metallics from railway wagon with crane. Manual shovelling at end
	3	Unloading metallics as before
Raw materials operator 3	1	Not sampled
	2	Helping and supervision of cleaning of conveyor belt system
	3	Working in port area- semi-enclosed space. Observing and directing other workers
Raw materials operator (crane)	1	Crane operator – unloading lead concentrate from ship
	2	As above. No direct contact with raw materials
	3	As above
Furnace operator	1	Routine control checks
	2	Using air chisel to remove lead from concrete channel during maintenance operation
	3	Furnace area control and cleaning work around conveyor belt at raw material feed points
Furnace operator	1	control test of electrostatic filter system in furnace area
	2	Assisting with maintenance of electrostatic filter system
	3	Raw material storage area. Driving forklift truck, unloading metallics from big bags. Slit open and dumping.
Furnace operator	1	routine control checks on emission filter systems in furnace
	2	maintenance of electrostatic filter system
	3	Transferring big bags with metallics using forklift
Furnace operator	1	Worked in control room all day
	2	As above
	3	As above

**Table A4** Job activity record Lead Refinery – Refinery and ancillary operations

<b>Job title</b>	<b>Sample interval</b>	<b>Activity prior to sampling</b>
Refinery operator 1	1	No details
	2	Sitting by lead casting machine regulating production of ingots. Some manual skimming of dross from molten metal
	3	Sitting at stamp machine where ingots are discharged
Refinery operator 2	1	Operating travelling crane, pumping molten metal between vessels. Scraping solidified lead with shovel
	2	As above
	3	As above
Maintenance 1	1	Routine checks in furnace area
	2	Repairs to pneumatic system for vibrating apparatus in raw materials transfer system. 1-hour work
	3	Making tools in workshop - mainly steel work
Maintenance 2	1	Control work in blast furnace area
	2	Maintenance on transfer lines/vibrator system in blast furnace area
	3	Working in tool shop
Maintenance 3	1	worked in stores and did some vehicle maintenance
	2	Handing out tools from store room. Changed wheel on loader used in raw materials area. Vehicle cleaned beforehand
	3	Working in tool shop and car repair shop
Quality control operator 1	1	Milling and sieving of samples for analysis
	2	Collection of samples from raw materials storage, battery paste and sludge
	3	No details
Quality control inspector 2	1	No details
	2	General inspection duties
	3	General inspection in Jetty and all over on bicycle
Quality control operator 3	1	Smelting metallics and lead bullion. Pouring into small moulds
	2	As above
	3	Collected samples of raw material from raw materials conveyors
Gate attendant	1	Gatehouse security all day
	2	As above
	3	As above

**Table A5** Job activity record Lead Chemical Plant

Job title – Subject code	Sample interval	Activity prior to sampling
Oxide plant operator 1	1	Loading furnaces with metal ingots. Driving forklift truck. (Hands V. dusty)
	2	Loading furnaces with metal ingots. Driving forklift truck. Routine sampling of litharge.
	3	As before. Used poker to loosen crust in chamber. Scooped back into process
Oxide Plant operator 2	1	Loading ingots to furnaces using automatic loading device. Driving truck and routine sampling of litharge.
	2	Loading ingots as before. Collecting samples (300-500 g) every 2 hours. Samples analysed in office.
	3	Normal routine work: Sampling and analysis of PbO every 2 hours
Vats 1	1	Slitting and tipping sacks of ingredients into vats charge hoppers.
	2	As before
	3	As before
Vats 2	1	Slitting bags and loading into vat
	2	No details – not sampled
	3	Slitting bags and loading into vat
Dryers/packing 1	1	Packing T90 (PbPO <sub>3</sub> ), Pb Stearate at the bagging station.
	2	Packing T90 (silo) , L51:(10*25kg), L28 (20*25kg), T80 (2*1000 kg)
	3	No details
Dryers/packing 2	1	Supervision in drier area. Misc. Transferring bag-bags and DEMAG containers using forklift
	2	As before
	3	As before. Note: Subject frequently did not wear gloves
Dryers/packing 3	1	Packing T3 (80*25 kg) bags at the number 1 drier
	2	Packing 25 kg bags (40 sacks)
	3	Some packing but helping out in effluent plant. Note: Dusty deposits around wrists at cuff of gloves
Effluent Plant 1	1	Supervision in drier area. Made batch of L51 into VAT. Worked at silos and walked around everywhere.
	2	Made batch of L51 at VAT. General supervision
	3	No details.
Effluent Plant 2	1	General supervision from control room
	2	Covered for Oxide plant operator (2-hours)
	3	No details. Note: dusty deposits around wrists at cuff of gloves.

**Table A6** Job activity record Lead Chemical Plant (Continued)

<b>Job title – Subject code</b>	<b>Sample interval</b>	<b>Activity prior to sampling</b>
Electrician	1	Maintenance on crane system.
	2	Working at effluent plant
	3	No details. Note hands very dusty. Gloves had burst.
Fitter	1	Working effluents plant control room
	2	Little work done - changed hydraulic rams
	3	General checks on plant
Blending/packing (Nafto) 1	1	Transfer bags of products, taking samples
	2	Batch change
	3	No details Note: Hands covered with blue coloured powder
Blending/packing (Nafto) 2	1	Packing T3 in 4 kg sachets (130 + 247 bags)
	2	Packing L28 (50*0.5 kg sachets). No breakages
	3	Continued packing of sachets.
Blending/packing (Gericke)	1	Mixing various chemicals (non-Pb). Shovelling, scooping out of bins
	2	No details
	3	Same as Period 1: - preparing batches
Engineering stores	1	General stores activities
	2	General stores activities
	3	General stores activities





# Applying science for a better working environment

## The Institute of Occupational Medicine

The IOM is a major independent centre of scientific excellence in the fields of occupational and environmental health, hygiene and safety. We aim to provide quality research, consultancy and training to help to ensure that people's health is not damaged by conditions at work or in the environment. Our principal research disciplines are exposure assessment, epidemiology, toxicology, ergonomics and behavioural and social sciences, with a strong focus on multi-disciplinary approaches to problem solving.

## Our beginnings

Our first major research programme began in the 1950s, on respiratory health problems in the coal mining industry. Major themes were quantification of airborne dust concentrations in different jobs, characterisation of types and constituents of the dusts, measurement of health effects, relationships between exposure and disease, and proposals for prevention. This research became an international benchmark for epidemiological studies of occupational health, and was the primary influence on dust standards in mines in the UK, US and other countries.

## Current themes

Our current work spans many other industries including asbestos, MMMF, pesticides, chemicals, energy, telecoms, metals, textiles, construction, agriculture as well as the environment. While diseases of the respiratory tract remain a major interest, our scope now extends to many other health outcomes such as mortality, cardiovascular effects, cancer, back pain, upper-limb disorders, hearing loss, skin diseases, thermal stress and psychological stress. Related work includes the development and application of measurement and control systems, mathematical models and survey methods.

## Who we work for

Our work in these areas is conducted for a wide range of organisations in the UK, the EU, and the US, including Government departments, international agencies, industry associations, local authorities, charitable organisations, and industrial and commercial companies. The IOM is a World Health Organisation (WHO) collaborating centre and is an approved institute of the Universities of Edinburgh and Aberdeen, enjoying collaborative research links with NIOSH, IARC, and many other institutes throughout the world.

## Publication

We believe that our research findings should be publicly available and subject to the scrutiny of the international scientific community. We publish our findings in the peer reviewed scientific literature and through our own series of Research Reports.

## Contact

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