EVALUATION OF A LEAD EXPOSURE REDUCTION INTERVENTION FOR SHUTDOWN MAINTENANCE CONTRACTORS AT A PRIMARY LEAD SMELTER

A thesis submitted for the degree of

Master of Medical Science

Julian SIBLY

BA, Dip Bus IR/HRM, Grad Dip OHSM

Discipline of Public Health

University of Adelaide

December 2009

ABSTRACT

Inorganic lead is a hazardous substance, exposure to which has been linked to various adverse health effects including haematological, neurological, renal and reproductive health problems. These adverse health effects can be correlated with blood lead levels (BLL) and are potentially significant for lead workers, such as production and maintenance personnel at lead smelters. Such workers usually need to wear particle-filtering respirators in order to reduce uptake of airborne lead, and follow strict hygiene protocols. However, there is a paucity of literature on the effectiveness of lead exposure reduction programs for lead smelter workers, especially those engaged as contractors for short periods.

The aim of this study was to evaluate an intervention targeted at maintenance and refurbishment contractors engaged during a two-yearly plant shutdown of a primary lead smelter. This evaluation addressed a variety of factors that influence the uptake of lead and gathered information on a rarely-studied group of contractors so as to provide recommendations for improving future occupational health and safety (OHS) interventions in lead industries. Findings from the research may assist in refining conceptual models of OHS interventions addressing complex exposure scenarios.

The intervention for the contractors entailed training and the mandatory use of a single brand of half-face disposable particle respirator. Contractors were instructed by the smelter management to undergo a pre-employment blood lead test and attend a health and safety induction, where they were informed of lead hazards and trained in the correct usage of disposable respirators. A post-induction questionnaire was used to elicit information on personal characteristics, smoking status, lead-based hobbies (hobbies that expose contractors to inorganic lead), prior respirator experience and perceptions of the use of disposable respirators. Fixed-position air sampling was conducted to determine the levels of airborne lead-bearing dust generated during maintenance activities and to assess differences between areas, including rest areas. Compliance with respirator usage requirements was assessed by routine observation, and site inspection checklists were used for the assessment of lead contamination. After the two-week shutdown period and prior to departure from the site, contractors underwent a second blood lead test. Other information was gathered prior to, during and after the intervention, through repeated observation and discussions with key stakeholders, and formed the basis of a stakeholder analysis.

Full questionnaire and blood lead data were available for 62 male contractors, and of these 81% were previous contractors to the smelter, 87% had previous respirator experience, 78% believed disposable respirators were equal in protection to non-disposable rubber respirators, 87% were confident disposable respirators would keep blood lead down, and 35% reported non-occupational exposure to lead. The arithmetic mean entry BLL was 5.5 μg/dl (std dev=3.9) and the increase in BLL over the shutdown period was 14.4 (9.3). Smokers (n=18) had a mean increase of 17.4 μg/dl, compared to non-smokers (n=44) with 13.2 μg/dl, but this difference was not statistically significant. Similarly, potentially predictive factors such as age, job category, lead-based hobbies, respirator experience and confidence were not statistically significant. Crane operators and riggers (n=8) had the greatest increase in BLL (19.6), compared with welders (17.1, n=9) and general maintenance contractors (13.0, n=45). Although it was a non-smoking site, many contractors were observed to smoke. Observed compliance with respirator usage was

generally good (estimated at 95% via direct observation). However it appeared that compliance and airborne lead dust levels were variable between locations, indicating these may be task related. Hot work, e.g. welding in confined areas, was associated with lower respirator usage and sweat-related respirator deterioration. Air monitoring in an area ostensibly lead-free, i.e. the blast furnace crib room (rest area), demonstrated appreciable levels of airborne lead dust (GM = 55 $\mu g/m^3$, n=4).

A stakeholder analysis of the intervention identified a lack of consultation between contractors and management prior to implementation. It was evident that smokers had difficulty complying with the strict non-smoking rules and that some contractors wore contaminated clothing in crib rooms, a source of lead exposure and a breach of policy. In addition, contractors were often unshaven, which significantly reduces the effectiveness of the mandated respirators. Finally, some contracting companies exhausted their supply of respirators, suggesting logistical problems and limited consultation.

This study appears to be the first to report increases in blood lead for a cohort of shutdown maintenance contractors working in a lead smelter environment. It also demonstrates appreciable BLL increases in a relatively short space of time.

The findings relating to airborne lead and to BLL differences between contracting companies indicate that lead uptake is associated with task and that the use of a half-face disposable respirator with moderate protection performance may not be suitable for all tasks. The lack of personal inhalational exposure data limits the interpretation of the effectiveness of the respiratory protection program based on BLL alone. The stakeholder analysis highlighted disparate management and contractor perspectives on consultation.

Overall, however, the intervention was judged as successful by the lead smelting company on the basis of observed respirator compliance and by a crude comparison with BLL data observed in a previous shutdown period, two years earlier.

It is recommended that task-specific personal air sampling be undertaken, especially for hot work, in order to determine whether the half-face respirator is adequate for all tasks. The induction training should more explicitly address routes of lead exposure and the importance of factors determining respirator effectiveness. A greater degree of consultation between contracting companies and smelter management should be undertaken in order to address logistics issues, work practices and hygiene, especially for smokers. This study has highlighted the complexity of exposure pathways, often mediated by worker behaviour in response to company directives, and relatedly, the value of stakeholder analysis as a means of identifying areas for improvement. The change in BLL serves as an index of actual success for future interventions.

ACKNOWLEDGEMENTS

The author wishes to thank his supervisors, namely Associate Professor Dino Pisaniello, Dr Afzal Mahmood and Associate Professor Peng Bi for their support and encouragement.

The author would also like to thank, Jerome Augustijn for advice and assistance with training, Mr Glen Bitmade from Trushape Engineering for invaluable contractor information.

Finally, the author gratefully acknowledges the assistance and cooperation of the management and health and safety personnel at the lead smelter.

STATEMENT

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.
I give my consent to this copy of my thesis when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968.

Signed

Date

TABLE OF CONTENTS

STATEMENT 4

TABLE OF CONTENTS 5

GLOSSARY AND ABBREVIATIONS 8

CHAPTER 1: LEAD HAZARDS AND MODES OF EXPOSURE IN LEAD SMELTERS 1

1.1 DESCRIPTION OF THE HEALTH HAZARD 1
1.2 ROUTES OF EXPOSURE 2
1.3 HEALTH IMPACTS OF LEAD EXPOSURE 2
1.4 SOURCES OF LEAD EXPOSURE 6
1.5 DESCRIPTION OF A LEAD SMELTER OPERATION 8
1.5.1 Blast furnace 9

CHAPTER 2: INTERVENTIONS FOR LEAD EXPOSED WORKERS 10

2.1 GENERAL MODEL FOR AN OHS INTERVENTION AND POTENTIAL POINTS OF EVALUATION 10
2.1.1 Definitions of OHS Interventions and Evaluations 10
2.1.2 Conceptual Model of an Occupational Health and Safety Intervention and Evaluation 10
2.1.3 Process and Effectiveness evaluation 13
2.1.4 Hidden Benefits of OHS interventions 14
2.2 LITERATURE REVIEW OF OHS INTERVENTIONS FOR LEAD EXPOSED WORKERS 15
2.2.1 studies of personal respiratory protection 15
2.2.2 hygiene practiCes 17
2.2.3 Smoking and lead 18
2.2.4 Organisational Culture 19
2.3 STUDIES OF MAINTENANCE CONTRACTORS 19
2.4 DESCRIPTION OF INTERVENTION 23
2.5 AIM OF STUDY AND RESEARCH QUESTIONS 26

CHAPTER 3: METHODS 27

3.1 INTERVENTION EVALUATION APPROACH 27
3.1.1 Study population 28
3.1.2 Types of activity 29
3.2 QUESTIONNAIRES AND FORMAL DATA-GATHERING PROTOCOLS 30
3.3 ETHICS CONSIDERATIONS AND APPROVAL 33
3.4 TRAINING AND INDUCTION SESSIONS 34
3.5 DATA ANALYSIS 36
3.6 FLOW CHART REPRESENTATION OF RESEARCH CONDUCTED 37

CHAPTER 4: RESULTS 38

4.1 ON SITE OBSERVATIONS 38
4.2 AIR SAMPLING 42
4.3 QUESTIONNAIRE DATA 43
4.4 BLOOD LEAD MEASUREMENTS 44
4.5 STAKEHOLDER ANALYSIS 47
4.6 WAS THE INTERVENTION SUCCESSFUL? 50

CHAPTER 5: DISCUSSION 51

5.1 OVERVIEW 51
5.2 STRENGTHS AND LIMITATIONS 51
5.2.1 Strengths 51
5.2.2 Limitations 51
5.3 INTERPRETATION OF RESULTS 52
5.3.1 Overall changes in BLL before and after shutdown and compliance 52
5.4 OPPORTUNITIES FOR IMPROVING THIS INTERVENTION 65

REFERENCES **68**
APPENDICES **75**
APPENDIX 1: INFORMATION SHEET **76**
APPENDIX 2: CONSENT FORM **77**
APPENDIX 3: INDEPENDENT COMPLAINTS FORM **78**
APPENDIX 4: POST INDUCTION QUESTIONNAIRE **79**
APPENDIX 5: RESPIRATORY HAZARD OBSERVATION **81**
APPENDIX 6: CRIB ROOM OBSERVATION CHECKLIST **82**

Table of tables	
Table 1	Health problems associated with blood lead
Table 2	Different respirator types and protection factors
Table 3	The results of observations of respiratory compliance
Table 4	Geometric mean airborne dust, lead and % lead in dust levels for fixed position air monitoring obtained at various locations during the maintenance shutdown
Table 5	Basic demographic information for all contractors who completed the post induction questionnaire
Table 6	Other background information from post-induction questionnaire
Table 7	Mean entry, exit and BLL changes
Table 8	Summary table of blood lead and questionnaire data
Table 9	Stakeholder Analysis

Table of Figures	
Figure 1	Dose-effect relationship for adverse health effects of lead exposure
Figure 2	Schematic representation of a lead smelter operation concentrating and sintering
Figure 3	Occupational Health and Safety Intervention Model Conceptual Mode
Figure 4	Blood lead levels for regular employees and contractors from May 2002 to August 2004

Table of Photographs	
Photograph 1	Top of blast furnace
Photograph 2	Front of blast furnace
Photograph 3	Disposable P2 respirator used in study
Photograph 4	Contractors on night shift conducting maintenance work
Photograph 5	Typical routine maintenance work contractors performed during day shift
Photograph 6	Crib Room with workers
Photograph 7	Air monitoring in the area adjacent to the blast furnace
Photograph 8	Author holding air monitors was well as disposable respirator used in the study and other mandatory PPE
Photograph 9	Illustrates some of the blast furnace area and the wet terrain is evident
Photograph 10	Crib room

GLOSSARY AND ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists *A standard-setting group based in the USA*
APF	Assigned Protection Factor *This is the estimated (or nominal) ratio of the concentration of the airborne contaminant outside the respirator to the concentration inside the respirator*
ANOVA	Analysis of Variance
ASCC	Australian Safety and Compensation Council (now SafeWork Australia)
BLL	Blood Lead Level, typically measured as micrograms per decilitre (μg/dl)
Crib Rooms	*Designated areas for workers to take meal and rest breaks*
Donning	*The process of putting on a respirator*
EPA	Environmental Protection Agency
GM	Geometric Mean
GSD	Geometric Standard Deviation
HEPA	High Efficiency Particulate Arrestor
IARC	International Agency for Research on Cancer
ILO	International Labour Organization
IOM	Institute of Occupational Medicine (UK)
MMAD	Mass Median Aerodynamic Diameter
NIOSH	United States National Institute for Occupational Safety and Health *Part of the CDC (Centers for Disease Control and Prevention) NIOSH is responsible for conducting research and making recommendations for the prevention of work-related illnesses and injuries.*
OHSI	Occupational Health and Safety Intervention *Interventions designed to improve occupational health and safety outcomes through identification and control of hazards in the workplace that are potentially harmful to health.*
OSHA	United States Occupational Safety and Health Administration *US health and safety regulatory agency*
PbA	Airborne Lead
PAPR	Powered Air Purifying Respirator
PEL	Permissible Exposure Limit *Exposure limits set and enforced by OSHA*
PPE	Personal Protective Equipment *Equipment designed for individuals to use to minimise exposure to hazards.*
SME	Small and Medium Enterprises
TWA	Time Weighted Average
WPF	Workplace Protection Factor *The ratio of the concentration of the air contaminant outside of the respirator to the concentration inside the respirator, worn during actual work activity.*