LEAD EXPOSURE OF CHILDREN ATTENDING PRE-SCHOOL FACILITIES IN CERTAIN GEOGRAPHICAL AREAS OF PRETORIA, IN RELATION TO THEIR ACTIVITY PATTERNS

A CROSS-SECTIONAL STUDY

by

JUANETTE JOHN

SUBMITTED IN PARTIAL FULFILLMENT FOR THE DEGREE MASTERS OF SCIENCE IN COMMUNITY HEALTH IN THE SCHOOL OF HEALTH SYSTEMS AND PUBLIC HEALTH

FACULTY OF HEALTH SCIENCES

AT THE

UNIVERSITY OF PRETORIA

SUPERVISOR: Prof C IJsselmuiden
CO-SUPERVISOR: Prof K Voyi

DATE: 12 June 2003

© University of Pretoria
SUMMARY

Objectives

• To estimate the exposure to lead of 5-year old children attending pre-school facilities in two different socio-economic areas, Pretoria East and Soshanguve in Pretoria, using existing exposure measurement tools, activity patterns and pollutant concentrations in air and soil;

• To determine the influence of external factors on the inhalation exposure of children to lead particles in air.

Population and methods

Design: Cross-sectional.

Setting: Pre-school facilities in Soshanguve, representing a lower socio-economic area, and in Pretoria East, representing a higher socio-economic area, during winter (July 2001).

Participants: Thirty pre-schools in Soshanguve (random sample) and 24 in Pretoria East (known pre-schools in the selected area), involving a total of 216 five-year old children; 120 from Soshanguve and 96 from Pretoria East.

Main outcome measures: Exposure to lead in air, lead concentrations in surface soil and dust, risk factors associated with inhalation exposure to lead particles.

Main measurement methods: Questionnaires, time-activity diaries, lead concentrations in air, soil and surface dust, statistical analyses.

Results: Environmental lead levels, especially in air, were generally low. No significant difference in estimates of indoor lead inhalation exposure was found between pre-schools in the two areas. Estimates of outdoor inhalation exposure were significantly lower in Soshanguve, as measured both by total inhalation exposure on the survey day and by traffic counts. The average surface dust lead loadings on window sills, and objects such as book cases, were significantly higher in Soshanguve. Average soil lead concentrations, including concentrations in sandpits and playground areas, were also significantly higher in Soshanguve.
Multivariate analysis indicated that mean log exposure to lead (assessing inhalation exposure - not differentiating by area) was associated with a variety of factors. For intervention purposes, five of these factors were selected as being the most important, on the basis of statistical testing. The variables of most practical importance were:

- monthly fees paid at the school
- sloping of the street on which the pre-school was located
- traffic volume
- number of children/m² outdoors, and
- surface area (m²)/child indoors

Inhalation lead exposure was positively associated with the first two and inversely associated with the last three variables.

Conclusions and Recommendations: Recommended factors to be considered when planning future pre-schools include the following:

- Proximity of the site to busy roads and other sources of lead. Traffic volumes on these roads should be monitored in advance.
- Facilities should not be built on sites close to steeply sloping roads.
- Cleaning procedures used at a pre-school should not use appliances that disperse dust so-as to minimize exposure to resuspended lead.
- Reduce time spent outdoors if the facility is close to sources of pollution.

As the scope of the study did not include quantification of the measures mentioned above, further research is recommended. This study did not sufficiently address the impact of activity patterns on exposure of children in a South African setting as compared to standardised exposure equations developed by the USEPA, warranting the need for further research in this field.
DECLARATION

I declare that this dissertation is my own, unaided work. It is being submitted for the Degree Masters of Science in Community Health at the University of Pretoria. It has not been submitted before for any other degree or examination at any other Technikon or University.

Juanette John

Signed on the 12th day of June 2003 in Pretoria
ACKNOWLEDGEMENTS

I would like to express my sincere thanks the following people and Institutions for their inputs into the thesis:

First and foremost, I would like to thank my Creator for strength to persevere throughout this process.

Mr Brent Christensen from the US Embassy for his assistance in obtaining additional funding.

The National Safety Council, through the US Environmental Protection Agency for partial funding of the study.

Dr Petro Terblanche for providing invaluable insights at the outset of the research.

Dr Elsie Calitz (VVOS) for providing useful contacts.

Ms Thembelani Mphokeng (Church Action in Need) for useful inputs at the outset of the study.

All pre-school facilities that gave inputs during the planning and pilot phase.

Environmental Science Services and the National Centre for Occupational Health for the use of their instruments.

Mr Joe Davidson from Transportek for the use of their traffic counters.

Ms Annemieke van Middelkoop for her useful inputs with regard the study design.

Prof Margo Schwab from Johns Hopkins University for invaluable inputs during the study design and approach of the study.

Dr Jonathan Levin for his patience in assisting me with statistical analyses.

Dr Zeleke Worku for assistance with statistics.

A special thanks to all my colleagues at work for their invaluable assistance and inputs at various stages:
Ms Ritthia Oosthuizen, especially for her help during the field work but also for review.
Ms Shirley McCormick, especially for preparation of filters before and after the field work.
Mr Nico Henning for acting as mentor and reviewer.
Ms Thabiso Mbugwana for spending long hours in the laboratory.
Mr Eddie Erasmus for his assistance in the laboratory.
Ms Yvonne Hong and Liz Muller for useful inputs during the review process.
Ms Annette van Zyl, Ms Karin Harding and Ms Helen de Beer for editorial assistance during the study.

My supervisors, professors Kuku Voyi and Carel IJsselmuiden for their guidance throughout the research.
The Environmental Health officers at Acacia City Council for sacrificing their time to assist in selection of the pre-school facilities.

Mr Fred Molelekwa and Mr Braam Aucamp from Technikon Northern Gauteng for allowing their students to take part in this study and for providing assistance with transport.

The students at the Technikon Gauteng North for taking part in this study.

All the staff and children at the pre-schools for their willingness to take part in the study.

Patricia Mangaladzi and Marlene Westmore for assistance with data capturing and cleaning.

Pat Brown and Johan van der Waals for assistance with matters relating to the capturing of geographic coordinates.

Althea Adey and Elize Webb for valuable editorial inputs into the study and Liz Wolfaardt for excellent support.

My husband, Alan, for his patience and encouragement during this whole period.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUMMARY</td>
<td>I</td>
</tr>
<tr>
<td>POPULATION AND METHODS</td>
<td>I</td>
</tr>
<tr>
<td>DECLARATION</td>
<td>III</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>IV</td>
</tr>
<tr>
<td>GLOSSARY</td>
<td>XIII</td>
</tr>
<tr>
<td>1. INTRODUCTION AND LITERATURE REVIEW</td>
<td>1</td>
</tr>
<tr>
<td>1.1 ENVIRONMENTAL HEALTH</td>
<td>1</td>
</tr>
<tr>
<td>1.2 HEALTH RISK ASSESSMENT FRAMEWORK</td>
<td>2</td>
</tr>
<tr>
<td>1.3 EXPOSURE ASSESSMENT</td>
<td>3</td>
</tr>
<tr>
<td>1.3.1 Variability and uncertainty in environmental exposure assessment</td>
<td>5</td>
</tr>
<tr>
<td>1.3.1.1 Variability</td>
<td>5</td>
</tr>
<tr>
<td>1.3.1.2 Uncertainty</td>
<td>5</td>
</tr>
<tr>
<td>1.3.2 Exposure pathways</td>
<td>5</td>
</tr>
<tr>
<td>1.3.3 Factors influencing exposure of individuals to pollutants</td>
<td>7</td>
</tr>
<tr>
<td>1.3.3.1 Characteristics of children of relevance to environmental exposure assessment</td>
<td>8</td>
</tr>
<tr>
<td>1.3.4 Pollutants of concern for children</td>
<td>16</td>
</tr>
<tr>
<td>1.3.4.1 Particulate matter</td>
<td>17</td>
</tr>
<tr>
<td>1.3.4.2 Heavy metals such as lead (Pb)</td>
<td>21</td>
</tr>
<tr>
<td>1.4 METHODS OF ESTIMATING EXPOSURE OF CHILDREN TO POLLUTANTS WITH SPECIFIC REFERENCE TO LEAD</td>
<td>24</td>
</tr>
<tr>
<td>1.4.1 Direct measurement of exposure</td>
<td>25</td>
</tr>
<tr>
<td>1.4.1.1 Micro-environmental samplers</td>
<td>25</td>
</tr>
<tr>
<td>1.4.1.2 Personal monitoring</td>
<td>25</td>
</tr>
<tr>
<td>1.4.1.3 Biological monitoring</td>
<td>26</td>
</tr>
<tr>
<td>1.4.2 Indirect measurement of exposure</td>
<td>27</td>
</tr>
<tr>
<td>1.4.2.1 Questionnaires</td>
<td>29</td>
</tr>
<tr>
<td>1.4.2.2 Time-activity patterns</td>
<td>30</td>
</tr>
<tr>
<td>2. AIMS AND OBJECTIVES</td>
<td>35</td>
</tr>
<tr>
<td>2.1 RATIONALE BEHIND THE STUDY</td>
<td>35</td>
</tr>
<tr>
<td>2.2 OBJECTIVES OF THE STUDY</td>
<td>36</td>
</tr>
<tr>
<td>2.3 RELEVANCE OF THE STUDY</td>
<td>37</td>
</tr>
<tr>
<td>3. POPULATION AND METHODS</td>
<td>39</td>
</tr>
<tr>
<td>3.1 STUDY DESIGN</td>
<td>39</td>
</tr>
<tr>
<td>3.1.1 Study population</td>
<td>39</td>
</tr>
<tr>
<td>3.1.2 Sample selection and sample size</td>
<td>40</td>
</tr>
<tr>
<td>3.1.3 Study area</td>
<td>43</td>
</tr>
<tr>
<td>3.2 PROCEDURES, MEASUREMENTS AND MEASUREMENT TOOLS</td>
<td>44</td>
</tr>
<tr>
<td>3.2.1 Physical measurements</td>
<td>45</td>
</tr>
<tr>
<td>3.2.1.1 Measurement of pollutant concentrations in air</td>
<td>45</td>
</tr>
<tr>
<td>3.2.1.2 Surface soil lead measurements (outdoors)</td>
<td>48</td>
</tr>
<tr>
<td>3.2.1.3 Surface dust lead measurements (mainly indoors)</td>
<td>48</td>
</tr>
</tbody>
</table>
3.2.2 Observational measurements ........................................................... 49
3.2.2.1 Time-activity diaries ................................................................. 49
3.2.2.2 Questionnaires........................................................................... 50
3.2.2.3 Determination of traffic counts over the exposure period .......... 50
3.2.3 Analyses of environmental samples.................................................. 50
3.2.3.1 Gravimetric determination of particulate matter concentrations ... 50
3.2.3.2 Determination of lead content of particulate matter ................. 51
3.2.3.3 Determination of lead in surface soil and dust......................... 51
3.2.4 Quality assurance .......................................................................... 52
3.2.4.1 Sampling and observations ...................................................... 52
3.2.4.2 Analyses ................................................................................... 53
3.2.4.3 Validation of questionnaire ...................................................... 54
3.3 PILOT STUDY ................................................................................... 54
3.4 ETHICS ........................................................................................... 55
3.5 DATA ANALYSIS .............................................................................. 56
3.5.1 Data capturing and cleaning ....................................................... 56
3.5.2 Preparation for data analysis ...................................................... 56
3.5.3 Creation of applicable variables ................................................... 57
3.5.3.1 Exposure variable .................................................................. 57
3.5.3.2 Distance of pre-school to the road where traffic counts were taken ........................................................................... 59
3.5.3.3 Location of the pre-school ...................................................... 59
3.5.3.4 Average lead in surface dust and surface soil ......... 59
3.5.3.5 Surface area/child indoors and outdoors .................. 60
3.6 LIMITATIONS OF THE STUDY .......................................................... 60

4. RESULTS ............................................................................................ 64
4.1 DESCRIPTIVE EPIDEMIOLOGY .......................................................... 64
4.1.1 Demographic information ............................................................. 64
4.1.1.1 Distribution of pre-schools ....................................................... 64
4.1.1.2 Distribution of children and teachers at pre-schools by area .... 65
4.1.1.3 Smoking status of teachers .................................................... 65
4.1.1.4 Monthly pre-school fees in the two areas ......................... 66
4.1.2 Fuels and fuel use ......................................................................... 66
4.1.3 Building characteristics and structure ......................................... 67
4.1.3.1 Windows and doors ............................................................... 67
4.1.3.2 Floor and building characteristics ........................................... 67
4.1.4 Play areas indoors and outdoors .................................................. 69
4.1.5 Cleaning practices indoors and outdoors .................................... 69
4.1.6 Other sources of pollution around pre-schools ......................... 69
4.1.7 Traffic and road parameters ....................................................... 69
4.1.8 Meteorological conditions on the day of the survey .................. 70
4.1.9 Time-activity patterns and exposure parameters ....................... 70
4.1.9.1 Parameters used to assess exposure ...................................... 70
4.1.9.2 Determination of inhalation exposure to lead in air at pre-schools ........................................................................... 72
4.2 ANALYSIS OF VARIANCE AT INDIVIDUAL AND PRE-SCHOOL LEVEL .......... 73
4.2.1 Variability of inhalation exposure ............................................... 74
4.2.2 Gender comparisons ................................................................. 75
4.3 FACTORS ASSOCIATED WITH INHALATION EXPOSURE AT PRE-SCHOOL LEVEL 76
4.4 OTHER STATISTICAL TESTS ............................................................. 81

5. DISCUSSION ....................................................................................... 82
5.1 EXPOSURE OF CHILDREN ATTENDING PRE-SCHOOL FACILITIES TO LEAD IN AIR. ........................................................................... 82
5.1.1 Time spent indoors versus outdoors ........................................... 82
5.1.2 Lead concentrations in the air ..................................................... 83
5.1.3 Exposure to lead in the air ................................................................. 84
  5.1.3.1 Blood lead as proxy for lead exposure ....................................... 85
  5.1.3.2 Factors impacting on lead exposure in air ................................ 86

5.2 Lead loadings and concentrations in soil as proxy for ingestion
    exposure indoors .............................................................................. 90
  5.2.1 Lead loadings in surface dust ...................................................... 90
  5.2.2 Concentrations in surface soil .................................................... 92

6. CONCLUSIONS AND RECOMMENDATIONS .............................................. 96

6.1 Ways to determine child-specific exposure parameters for use in
    health risk assessment ....................................................................... 97

7. REFERENCES ............................................................................................ 167
# LIST OF APPENDICES

<table>
<thead>
<tr>
<th>APPENDIX</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>NAMES OF THE PRE-SCHOOL FACILITIES PARTICIPATING IN THE STUDY</td>
<td>100</td>
</tr>
<tr>
<td>B.</td>
<td>SPATIAL DISTRIBUTION OF THE TWO STUDY AREAS IN RELATION TO EACH OTHER</td>
<td>101</td>
</tr>
<tr>
<td>C.</td>
<td>INSTRUCTIONS AND RECORDING SHEET FOR AIR MONITORING</td>
<td>102</td>
</tr>
<tr>
<td>D.</td>
<td>INSTRUCTIONS AND RECORDING SHEET FOR SOIL AND SURFACE DUST MONITORING</td>
<td>104</td>
</tr>
<tr>
<td>E.</td>
<td>TYPES OF ACTIVITIES INCLUDED IN DIFFERENT LEVELS OF ACTIVITIES SPECIFIED</td>
<td>109</td>
</tr>
<tr>
<td>F.</td>
<td>TIME-ACTIVITY DIARY TEMPLATE</td>
<td>110</td>
</tr>
<tr>
<td>G.</td>
<td>QUESTIONNAIRE FOR ADMINISTRATION TO TEACHER IN CHARGE AND ONE OTHER MEMBER OF STAFF IF POSSIBLE</td>
<td>115</td>
</tr>
<tr>
<td>H.</td>
<td>INSTRUMENTAL CONDITIONS FOR THE ICP-MS</td>
<td>126</td>
</tr>
<tr>
<td>I.</td>
<td>LABORATORY CONDITIONS FOR GRAVIMETRIC ANALYSES</td>
<td>127</td>
</tr>
<tr>
<td>J.</td>
<td>FLOW DIAGRAM OUTLINING EXECUTION OF STUDY</td>
<td>128</td>
</tr>
<tr>
<td>K.</td>
<td>LETTER OF CONSENT: DEPARTMENT OF EDUCATION</td>
<td>129</td>
</tr>
<tr>
<td>L.</td>
<td>LETTER OF CONSENT: TSHWANE HEALTH SERVICES</td>
<td>131</td>
</tr>
<tr>
<td>M.</td>
<td>LETTER TO PRINCIPAL OF SELECTED SCHOOL</td>
<td>132</td>
</tr>
<tr>
<td>N.</td>
<td>INFORMATION SHEET TO PARENTS</td>
<td>135</td>
</tr>
<tr>
<td>O.</td>
<td>QUESTIONNAIRE STRUCTURE AS USED FOR DATA ANALYSES INCLUDING VARIABLE NAMES</td>
<td>138</td>
</tr>
<tr>
<td>P.</td>
<td>FORMULAS USED FOR CREATION OF VARIABLES USED IN ANALYSES</td>
<td>145</td>
</tr>
<tr>
<td>Q.</td>
<td>RESULTS</td>
<td>146</td>
</tr>
<tr>
<td>R.</td>
<td>STATA DATA OUTPUTS</td>
<td>160</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

Figure 1. Environmental health hazard pathway ........................................... 2
Figure 2. Health Risk Assessment framework .................................................. 3
Figure 3. General environmental exposure pathways ...................................... 6
Figure 7. Mean duration of time spent indoors and outdoors at pre-schools in 
(a) Soshanguve and (b) Pretoria East ....................................................... 71
Figure 8. Comparison of indoor versus outdoor exposure to lead in the air in 
(a) Soshanguve and (b) Pretoria East ....................................................... 72
Figure 10. Frequency distribution of exposure of 5-olds attending for more than 
6 h on survey day in (a) Soshanguve and (b) Pretoria East ....................... 73
Figure 4. Diagram outlining the selection process in the two areas .............. 154
Figure 5. Temperature distribution on the various survey days (Source: SA 
Weather Service) ..................................................................................... 155
Figure 6. Wind rose indicating prevailing wind direction in July 2001 
(Source: SA Weather service) ................................................................. 156
Figure 9. Box and whisker plot indicating distribution of mean exposure at 
pre-schools in (a) Soshanguve and (b) Pretoria East ............................. 157
Figure 11. Scatter plot of mean exposure on the survey day by average 
temperature on the particular day for the two areas under 
consideration ............................................................................................. 157
Figure 12a. Total exposure of individuals by area ........................................ 158
Figure 12b. Log transformed total exposure of individuals by area .............. 158
Figure 12c. Mean exposure at pre-schools by area ...................................... 158
Figure 13. Box plot indicating the distribution of exposure by gender .......... 159
LIST OF TABLES

Table 1. Pollutants of concern for children and pathways of exposure........ 17
Table 2. Measurement of particulate matter: Usefulness of site and duration of measurements................................................................. 19
Table 3. Traffic density and atmospheric lead in Cape Town in 1996 .......... 22
Table 4. Different indicators of lead exposure........................................... 27
Table 21. Variables tested to find factors that seem to be associated with mean exposure............................................................................. 76
Table 5. Number of pre-schools participating each day over the monitoring 146
Table 6. Distribution of children and teachers at pre-schools on the survey day....................................................................................... 146
Table 7. Gender distribution of children observed in the two areas............. 147
Table 8. Weight distribution of the children observed in the two areas........ 147
Table 9. Types of energy sources used for cooking by area ......................... 147
Table 10. Type of cooking apparatus used by area ...................................... 148
Table 11. Types of energy sources used for heating at pre-school facilities by area..................................................................................... 148
Table 12. Distribution of types of building materials.................................... 148
Table 13. Number of rooms that 5-y olds normally play in.......................... 149
Table 14. Characteristics of surface area of areas indoors and outdoors in which 5-year olds spend most of their time............................. 149
Table 15. Distribution of types of materials of the playground that 5-year olds mainly play on............................................................... 149
Table 16a. Road and traffic parameters by area........................................... 150
Table 16b. Motor vehicle counts in two areas.............................................. 150
Table 17. Meteorological conditions on the survey day............................... 150
Table 18. Time-activity parameters for the two areas (in minutes, unless indicated otherwise).............................................................. 151
Table 19. Distribution of pollutant concentrations in the two areas............. 152
Table 20. Exposure in the two areas (indicated in μg/m³ * h)...................... 153
GLOSSARY

Absorption
The process of active or passive transport of a substance, across biological membranes or other barriers, into an organism.

Acute exposure
A single exposure to a toxic substance that results in severe biological harm or death.

Air particulates
Airborne particulates include windblown dust, emissions from industrial processes, smoke from the burning of wood and coal, and motor vehicle or non-road engine exhausts.

Air pollutant
A potentially harmful agent occurring in the air usually as a result of human activities.

Ambient air
Any unconfined portion of the atmosphere: open or outdoor air.

Background level
In toxic substances monitoring, the average presence of a substance in the environment.

Biomarkers
A measure of a chemical, cellular, immunologic, genetic, or physiologic signal or biologic event or state in biological media, including in tissue, cells or fluids.

BTech in Environmental Health
Bachelors degree in Technology consisting of a year of study after completing a national diploma in Environmental Health at a South African Technikon.
Chronic effect
An adverse effect on a human, animal or vegetation in which symptoms recur frequently or develop slowly over a long period of time.

Cyclone
A cyclone is a device used to separate coarse and fine suspended particles.

Developmental disorders/effects
Adverse effects such as altered growth, structural abnormality, functional deficiency, or death observed in a developing organism.

Dose
The amount of a substance to which a person is exposed, often expressed in relation to body weight.

Dose-response
The process of characterising the relationship between the dose of an agent administered or received and the incidence of an adverse health effect in exposed populations.

Emission
Pollution discharged into the atmosphere from smokestacks, other vents, and surface areas of commercial or industrial facilities; from residential chimneys; and from motor vehicle, locomotive, or aircraft exhausts.

Environmental fate
The destiny of a chemical or biological pollutant after release into the environment, involving temporal and spatial considerations of transport, transfer, storage and transformation.

Environmental Tobacco Smoke (ETS)
‘Second hand smoke’; tobacco smoke inhaled by someone in proximity to a smoker.
Exposure
Contact with a chemical by swallowing, by breathing, or by direct contact such as through the skin or eyes. Exposure may be short term (acute) or long term (chronic).

Exposure assessment
Identifying the pathways by which toxicants may reach individuals, estimating how much of a chemical an individual is likely to be exposed to, and estimating the number of individuals likely to be exposed.

Exposure variable
A variable estimating inhalation exposure to lead, created in this study. This variable incorporated data on time-activity patterns and lead concentrations in air. Lead concentrations in soil and dust were measured as proxies for ingestion exposure.

FEV₁
A measure of the maximum amount of air during a forced vital capacity determination that can be expelled in 1 second.

Hazard
A source of risk that produces risk only if an exposure pathway exists, and if exposures create the possibility of adverse consequences.

Hazard identification
Determining if a chemical can cause adverse health effects in humans and what those affects might be.

Hazardous substance
Any material that poses a threat to human health and/or the environment. Typical hazardous substances are toxic, corrosive, ignitable, explosive, or chemically reactive.
Heavy metals
Metallic elements with high atomic weights, e.g., mercury, chromium, cadmium, arsenic, and lead; can damage living things at low concentrations and tend to accumulate in the food chain.

High risk community
A community located within the vicinity of numerous sites or facilities or other potential sources of environmental exposure/health hazards that may provide high levels of exposure to contaminants or pollutants.

Indicator/proxy
In biology, an organism, species, or community whose characteristics show the presence of specific environmental conditions.

Indoor air
The air inside a habitable structure or means of transportation.

Indoor air pollution
Chemical, physical, or biological contaminants in indoor air.

Ingestion
Swallowing, such as eating or drinking, during which chemicals can get inside the body.

Inhalation
Exposure may occur from inhaling or breathing in contaminants because they can be deposited in the lungs, taken into the blood, or both.

Lead (Pb)
A heavy metal that is hazardous to health if breathed or swallowed.

Mean exposure
Mean inhalation exposure of 5-year olds attending 6 hours and more, determined in this study. If all four children at a pre-school were eligible for inclusion, the mean exposure consists of the
average of four observations. If only one child was eligible for inclusion, the mean exposure consists of the exposure of the one child.

**Mean log exposure**
Log transformed variable of mean exposure, assessing inhalation exposure to lead (see mean exposure)

**Mbawula**
A container with holes at the bottom used for cooking and heating purposes

**Micro-environment**
A physical three-dimensional space with a well-characterised, relatively homogenous pollutant concentration level over a specified period of time.

**Monitoring**
Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.

**NIOSH**
National Institute of Occupational Health and Safety

**Particulate Matter**
Collective term used to describe small solid and liquid particles that are present in the atmosphere over relatively brief to extended periods of time.
PM\textsubscript{10} and PM\textsubscript{2.5}: Particulate matter with an aerodynamic diameter of less than 10 and 2.5 \(\mu\text{m}\) respectively.

**Respirable suspended particulate matter (RSP)**
This is the respirable fraction of airborne particulates based on the internationally accepted ‘Johannesburg Curve’ for size distribution, i.e. particle aerodynamic diameter of less than 7.0 micron (i.e PM\textsubscript{7.0} \(\mu\text{m}\)) \(^2\). This terminology is used instead of PM\textsubscript{10} (particulate matter with
diameter less than 10 μm) as the cyclones used in the study have a cut-off point of 7 μm.

**Total suspended particulate matter (TSP)**

This refers to all airborne particulates as collected by a personal gravimetric sampler without particle size selection.\(^1\)

**Typical winter day**

A sunny day where the day temperatures average 16 ± 4 °C.\(^3\) in Pretoria.

**USEPA**

United States Environmental Protection Agency