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Blood Lead Levels and Likely Adverse Health Outcomes in Under Five Children in Kabwe, Zambia

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Abstract

The aim of this study is to determine blood lead levels which can lead to adverse health outcomes in under five children in Kabwe (Makululu Township). This study was a cross-sectional study based on secondary data collected in 2015 by Misenge environmental and technical services (METS) ltd, a subsidiary of ZCCM-Investments Holdings Plc. The study was conducted in four zones (Zambezi, Moomba, Makululu, Chililalila) with proximity to the closed Kabwe mine. The study population was children under five, in Makululu Township and study sample was conveniently selected from the study population. All under five children brought to Kabwe mine clinic from Makululu Township were measured for their blood lead levels, until a sample size of 1,166 was reached

Blood samples were taken and analyzed in the laboratory for lead concentrations by a professional staff; under the supervision of a medical officer at Kabwe Mine Clinic where lead-Care blood testing system was used. A small, capillary sample of blood (50µl) was drawn using sterile equipment and aseptic techniques. Demographic information (identity number, age, sex, community, and zones) were captured on a form before collection of blood.

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The total number of participants was 1,166 and out of these 50.9% was female, while 49.1% were male. From the blood lead levels conducted, 99.4% of the children were at risk, while 73.2% required chelation. The results revealed that there was a statistically significant association between age and blood lead levels and with every decrease of age by one year, there was an increase in blood lead levels by 0.40%. All zones required chelation in those children with blood lead levels above 25 µg/dL.

This study has reported high percentages of under five children who are at risk (99.4%) of health effects associated with lead exposure or poisoning. This result is not different from other studies conducted regionally. These results therefore, require an expansive and integrated programme of lead exposure prevention. The programme should be implemented by government and co-operating partners. The programme should also take into account environmental management and disease surveillance related to lead exposure in an effort of reducing the high risk (99.4%) of health effects associated with Lead exposure.

Keywords: Lead; Exposure; Contamination; Risk; Chelation; Lead levels.

1. Introduction

Kabwe town is located about 150 kilometres north of the nation's capital city of Lusaka, and is one of six towns in close proximity to the Copperbelt. In 1902, zinc and lead deposits were discovered there and immediately mining and smelting commenced and this was allowed to operate for almost continuously until 1994 without addressing the potential dangers of lead contamination. The mine and smelter are no longer operating but have left a city poisoned by debilitating concentrations of lead dust in the soil and by metals in the water. In one study, the dispersal in soils of lead, cadmium, copper, and zinc extended over a 20 km radius at levels which were much higher than those recommended by the World Health Organization [1, 2].

A small waterway runs from the mine to the center of the town and this has been used to carry waste from the once active smelter. Currently, there are no safeguards or restrictions on use of the waterway resulting in local children using it for bathing. In addition to contaminated water, dry, dusty and lead-laced soils near residential home result into a significant source of contamination for the locals. Most workers and residents of Kabwe are exposed to toxic levels of lead through inhalation of dust in these areas [1].

Kabwe District has a total population of 203,000 and much of this population is found within the urban areas of the district. The surrounding areas of Kabwe have been known through numerous studies to be highly contaminated with Lead which is found in soil drawn from the smelter stack of active mine. Kabwe's geology is predominantly that of carbonate and lead which usually cause lead poisoning from polluted flows of soil erosion and leachate. Although studies in Kabwe have shown relatively low levels of soluble lead, atmospheric Lead pollution has been found to be a major contaminant of food crops, especially maize which is a staple food crop consumed by many [3].

The author in [4] states that on average, children's blood lead levels in Kabwe exceeded the recommended levels by five to ten times. This was as a result of contamination from lead mining in the area because of smelting which was largely unregulated throughout the 20th century.

These smelters released heavy metals in the form of dust particles, which later settled on the ground in the surrounding areas. Thus although the mine is closed, currently artisanal activity at tailings continues taking place. The current centre for disease control (CDC) recommended blood levels lead in children is 5 ug/dL as levels in excess of 120 ug/dL can potentially be fatal. In some neighbourhoods in Kabwe, blood concentrations of 200 ug/dL or more were recorded in children with an average blood levels in children ranging between 50 and 100 ug/dL. Thus those at high risk are children who play in the soil and young men who mine the area. The author in [4] noted that the Zambian government has made significant progress in dealing with the issue, particularly through a remediation program under World Bank and Nordic Development Fund which was conducted between 2003 and 2011. However, despite these efforts, the site still poses an acute health risk that will require further work [4].

Makululu township in Kabwe, is one of the most impacted by the prevailing westerly winds that blow through the lead mine carrying with it lead particles from the waste ore dump and smelter stack from active mine.

The Kabwe Mine Lead and Zinc Complex officially closed down on 30 June 1994 with the site being placed under Copperbelt Environmental Project (CEP) because of it being classified as an environmental liability for Zambia Consolidated Copper Mines Investments Holdings Plc (ZCCM-IH). The main aim of establishing CEP was to address environmental liabilities associated with the mining sector that accumulated over a period of more than 80 years of mining following the privatisation of Zambia Consolidated Copper Mines (ZCCM). It was established to assist the Government of the Republic of Zambia and ZCCM-IH implement a set of mitigating measures designed to help alleviate environmental and social liabilities that resulted from the ZCCM privatisation process and closure of the Kabwe Mine.

Some of the programs which were implemented in Kabwe by CEP in mitigating lead contamination included; integrated case management (ICM) with focus on children that had elevated blood lead levels (EBLLs), given food supplements to children with elevated blood lead levels, improvements to borehole water supply, planting grass and Moringa trees for environmental mitigation and intensive health education related to prevention of lead exposure. CEP has since phased out and its activities have been taken over by Misenge environmental and technical services (METS) LTD, which is a subsidiary of ZCCM- Investments Holdings Plc.

Regionally several studies have been conducted such as one which was conducted by South African Medical Research Council which measured elevated levels of lead in the blood for certain South African children [30]. Similarly, other studies which were conducted in the early 1990s indicated that 90% of the urban South African children studied had blood levels that were higher than the internationally accepted action level of 10 µg/dl [5].

Globally, lead is the most widely used of the toxic heavy metals and this is used for various purposes, resulting in a variety of health hazards due to environmental contamination and workplace exposure. It is also used as an additive in petrol, paint, batteries, candles, crystal glass, cellular telephones, computers, television sets, pottery, ammunition, protective clothing, fishing, wheel-balancing weights and tobacco [6] plus traditional medicines and in South Africa [7]. Human exposure occurs mainly through ingestion and inhalation, and to a lesser degree through dermal absorption.

Lead is a soft, blue-gray metal. It is a naturally occurring metal and is very stable and resistant to corrosion, though it dissolves in acidic water and is able to leach out of pipes, fittings and solder. It exists in both organic and inorganic forms. Inorganic lead is found in old paint or buildings, soil, leaded gasoline and various products [8].

In most cases, toxic blood lead levels (BLLs) reflect a mixture of current exposure to lead and endogenous contribution from previous exposures. An acute high exposure to lead can, however, lead to high short-term BLLs and cause symptoms of lead poisoning. It is therefore important that Primary Care Physicians evaluate a patient with potential lead poisoning by examining potential, current and past lead exposures and by identifying other factors that affect the biokinetics of lead such as pregnancy and poor nutrition [9].

Lead is most harmful to children under the age of six years because it is easily absorbed into their growing bodies and interferes with the developing brain and other organs and systems. The blood lead exposure effects are divided into three groups which are related to levels of exposure, viz.:- very high levels (60 - 120µg/dl), low levels (10 µg/dl - 59) and very low (<10µg/dl) [10]. At very high levels of exposure (60-120 µg/dl) lead poisoning can cause mental retardation, coma, convulsions, and even death.

At low levels (10 - 60µg/d), lead poisoning may not present identifiable symptoms, and a blood or tooth test may be used to determine if a child is poisoned. Symptoms may include hearing loss, insomnia and a range of other health, intellectual and behavioural problems.

At very low levels of exposure in children (<10 µg/dl) it has been associated with higher absenteeism in school, poor vocabulary and grammatical reading scores, longer reaction time, poor hand-eye coordination and impaired growth [10]. It is also associated with reduced attention span [11]. The incomplete development of the blood-brain barrier in the foetus and every young child (up to 36 months of age) increases the risk of lead's entry into the developing nervous system, which can result in prolonged or permanent neuro-behaviour disorders [12,13].

2. Material and Methods

2.1. Study design and participants

Study design*:* This is a cross-sectional study based on secondary data collected by Misenge environmental and technical services (METS) LTD, a subsidiary of ZCCM- Investments Holdings Plc, in the year 2010.

Study setting*:* The study was conducted in four zones (Zambezi, Moomba, Makululu, Chililalila) in Makululu township, Kabwe Districts. These areas were chosen because of the proximity to the closed Kabwe mine.

Study Population*:* The study population was children under five, in Makululu Township. The study sample was conveniently selected from the study population. All those under five children brought to the Kabwe mine clinic coming from Makululu Township were measured for blood lead levels, until a sample size of 1166 was reached

2.2. Data collection

The study used secondary data captured by Misenge environmental and technical services (METS) LTD, a subsidiary of ZCCM- Investments Holdings Plc. Data collection procedures were as follows:

2.2.1. Blood Sampling

Blood samples were taken and analyzed for lead concentrations at Kabwe Mine Clinic. The Lead-Care blood testing system was used. A small, capillary sample of blood (50µl) was drawn using sterile equipment and aseptic techniques.

The blood sample was taken by professional staff, under the supervision of a medical officer and later analysed in the laboratory by qualified personnel.

2.2.2 Form data

Form data was filled in before blood samples were taken. Form data captured demographic information, which included, identity number, age, sex, community (Makululu), and zones (Zambezi, Moomba, Makululu, Chililalila) and a space for writing blood lead levels.

2.2.3. Compliance with Ethical Standards

All procedures performed in the study involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Ethical approval was obtained from the Biomedical Research Ethics Committee (BREC) of the University of Zambia. The parents/guardians to the study participants signed informed consent prior to participating in the study.

3. Results

The total number of study participants was 1,166 and out these 50.9% were female, while 49.1% were male. The majority of the participants (43.6%) were equal or greater than 5 years of age, while 30.4% were between 3 to 4 years and 26.0% were between 1 to 2 years of age. The highest number of the study participants came from Makululu Township (47.9%), while the least number of study participants came from Mooba Township (16.0%). From the blood lead levels conducted, 99.4% children were at risk, while 73.2% required chelation (Table 1).

Table 2: Age and Blood lead levels (descriptive characteristics)

	Mean	**SD**	**Median**	**Min**	**Max**
Age (Years)	4.1	1.8	4.0	1	8
Blood lead levels (µg/dL)	36.9	18.1	32.6	0	99.2

The mean blood lead levels and age of the participants were 36.9 µg/dL and 4.1 years respectively (Table 2).

Table 1: Demographics and personal characteristics

	n	%
Sex		
Male	572	49.1
Female	594	50.9
Age		
1-2 years	303	26.0
3-4 years	355	30.4
≥ 5 years	508	43.6
Zone		
Chililalila	244	20.9
Makululu	559	47.9
Moomba	186	16.0
Zambezi	177	15.2
Children Risk		
Not at Risk < 10 µg/dL	7	0.6
At Risk > 10 µg/dL)	1159	99.4
Chelation		
< 25 µg/dL	313	26.8
≥ 25 µg/dL	853	73.2

Table 3: Zone by Blood lead levels

Zone	N	Mean	SD	95%CI	Min	Max
Chililalila	244	35.5	17.5	33.3, 37.7	0	98.3
Makululu	559	36.4	17.9	34.9, 37.9	8.5	99.2
Moomba	186	38.8	19.0	36.1, 41.6	3.1	98.2
Zambezi	177	37.7	18.5	35.0, 40.4	8.7	93.4

Anova; p=0.234

There was no association between zones and blood lead levels (Table 3).

Table 4: Age by Blood lead Levels

Variable	p	Coef	95%CI
Age	<0.001	-0.40	-4.44, -3.39

Simple linear regression p=0.001

There was a statistically significant association between age and blood lead levels. With every decrease of age by one year, there was an increase in blood lead levels by 0.40% (Table 4).

Table 5: Age category by Blood lead levels

Age category	N	Mean	SD
1-2 years	303	48.0	22.8
3- 4 years	355	36.2	14.9
≥ 5 years	508	30.6	13.2

Anova; p= 0.001

There was a significant association between blood lead levels and age categories. Children between 1 to 2 years had higher mean blood lead levels, while the lowest was for those children equal or above 5 years of age (Table 5)

Table 6: Sex by Blood lead levels

Sex	N	Mean	SD
Male	572	37.3	18.7
Female	594	36.3	17.7

T-Test; p=0.308

There was no significant association between Blood lead levels and sex (Table 6).

Table 7: Zone by Chelation

	< 25	**≥ 25**
Zone	**N (%)**	**N (%)**
Chililalila	76 (24.3)	168 (19.7)
Makululu	160 (51.1)	399 (46.8)
Moomba	37 (11.8)	149 (17.5)
Zambezi	40 (12.8)	137 (16.1)

Cross tab (Contingency table); p=0.024

There was significant association between zones and chelation. All zones required chelation in those children with blood lead levels above 25 µg/dL. The children which required chelation in Moomba and Zambezi were more than those that did not require Chelation in the same areas respectively (Table 7).

Table 8: Sex by Chelation

Sex	< 25 N (%)	≥ 25 N (%)
Male	153 (48.9)	419 (49.1)
Female	160 (51.1)	434 (50.9)

Cross tab test; p=0.942

There was no statistical significance between chelation and sex. Both females and males were equal in terms of chelation requirements (Almost equal percentages) (Table 8).

4. Discussion

The study was conducted in Makululu Township which has four Zones and these include; Zambezi, Moomba, Chililalila and Makululu. This sentinel study in under five children in Kabwe, Zambia, reflects a growing need to take a critical look at how lead exposure in under five children should be prevented.

The mean blood lead levels (BLLs) in this study were found to be 37.3 µg/dL and 36.3 µg/dL in male and female respondents respectively. These figures exceeded recommended levels by the centre for disease control (CDC) by more than seven times. The current CDC recommended lead level in children's blood is 5 ug/dL [10]. These results are therefore similar to earlier study results, which was conducted in 2006 in the same area, which revealed that on average children's blood lead levels in Kabwe exceeded recommended levels by five to ten times [1]. However, the most striking feature when we compare these two study results is that from 2006, when the other study was conducted to 2015 when this study was conducted, there has never been any improvement in the blood lead levels in under five children in Kabwe. The reason for this is either due to environmental mitigation programmes and integrated case management (ICM) program which focused on children that had elevated Blood lead levels (EBLLs) has not been effective.

For instance the trend being practiced at Kabwe mine clinic is that those under five children with BLLs ranging from < 10 µg/dl to 30 µg/dl just receive home visits from health workers. Chelation is only commenced on those under five children with BLLs above 31 µg/dl. This is contrary to CDC recommendations, which stipulates that allowable BLLs in under five children should be 5 µg/dl and chelation should be commenced when BLLs reach at least 25 µg/dl [29]. If the above BLL allowable limit by CDC is implemented in under five children in Kabwe, it will help in alleviating health effects associated with lead exposure, especially considering that in this study, children who were at risk of health effects associated with lead exposure (> 10 µg/dl) [29] were 99.4%, while those that required chelation (≥25 µg/dl) were 73.2%.

The under five children in Moomba and Zambezi zone who required chelation among the study population exceeded those who didn't require chelation (<25 µg/dl) in the same areas respectively. Results in this study also showed that both female and male respondents were equal in terms of chelation requirements.

In this study, the results have shown that with every decrease of age by 1 year, there was an increase in BLLs by 0.45%. The highest mean blood lead levels were recorded in children between 1 to 2 years and with those children equal or above 5 years recording the lowest. The reasons for this result is not clear, perhaps it is due to the fact that as age decreases from five years, it is always expected that children would play more with soil as they craw. In the case of those children who were much younger, this probably could be due to exposure to lead through pregnancy and other pathways.

With the above blood lead levels (BLLs), you would expect lead related health effects from the population under study. The health effects could include at very low levels of exposure in children (<10 µg/dl); higher absenteeism in school, poor vocabulary and grammatical reading scores, longer reaction time, poor hand-eye coordination and impaired growth [10,15]. It is also associated with reduced attention span [11,31]. The incomplete development of the blood-brain barrier in the foetus and every young child (up to 36 months of age) increases the risk of lead's entry into the developing nervous system, which can result in prolonged or permanent neuro-behaviour disorders [13]. Similarly, at low levels (10 - 60µg/d) symptoms may include; hearing loss, insomnia and a range of other health, intellectual and behavioural problems [22]. Furthermore, very high levels of exposure (60 -120 µg/dl) to lead poisoning can cause; mental retardation, coma, convulsions, and even death [17,18,28].

The results of minimum and maximum BLLs in this study ranged from 0 µg/dL to 99.2 µg/dL respectively. Thus in this case you would naturally expect all the above health effects in the study population of Kabwe.

5. Conclusion

In conclusion, lead exposure still remains a public health problem in Kabwe and globally [19]. This study has reported high percentages of under five children who are at risk (99.4%) of health effects associated with lead exposure or poisoning. This result is not different from other studies conducted regionally where in the early 1990s, for example, indicated that 90% of the urban South African studied children had blood lead levels that were higher than the internationally accepted action level of 10 µg/dl [5]. These results therefore, require an expansive and integrated programme of lead exposure prevention to be implemented by government and co-operating partners [20]. The programme should take into account environmental management and disease surveillance related to lead exposure and it should focus on continuous process of environmental monitoring of lead levels, and also to continue the earlier project initiated by CEP in Kabwe, of lead contamination mitigation.

6. Recommendations

This paper therefore would like to recommend improved preventive measures to the ones undertaken by Copperbelt Environmental Project (CEP).

The preventive measures should include; improved supply of palatable and wholesome domestic water through drilled boreholes with regular sampling and testing of water for lead poisoning in the community. Planting of grass (Kapinga) and Moringa trees in the community, tailings and surrounding areas to improve top soil covering. This should include watering of the surrounding areas to prevent rising of dust. The interventions should also include disease surveillance programmes to focus on under five children chelation for those with BLLs above 25 µg/dl. Health education to mothers and supply of food supplements to under five children should be encouraged. There is also need to design information, education and communication (IEC) in addition to formulation of women clubs and drama groups to spearhead dangers associated with lead poisoning exposure in the area. These interventions would go a long way in reducing the high risk (99.4%) of health effects associated with lead exposure [21].

7. Limitations

The limitation to this study is that the research was based on secondary data which did not take into account other social variables like; nutritional status, levels of education, poverty levels and parenting factors as these would have adversely affected direction of the final results. This is taking into consideration of findings from one study [22], which states that current lead exposure accounts for a very small amount of variance in cognitive ability (1–4%), whereas social and parenting factors account for 40% or more. Thus, taking in to account of the above confounding variables could have given a true reflection of their modifying effect to the children's cognitive faculties. This finding has been well noted in the other studies as well [16,22,23,24,25,26,27].

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Conflict of interest: The authors declare that they have no conflict of interest.

References

[1] Blacksmith Institute. The Silent Death: Lead Poisoning in Kabwe, Zambia, 2001.

[2] B. Leteinturier, J. Laroche, J. Matera and F. Malaisse Reclamation of lead/zinc processing wastes at Kabwe, Zambia: a phytogeochemical approach. South Africa Journal of Science 97 624-627), 2001.

[3] World Bank Implementation completion Report (ICR) Review- Zambia Copperbelt Environmental Project (CEP), 2012.

[4]Blacksmith Institute. Environmental Assessment Project – Kabwe, Zambia, 2014. Available from http://www.pureearth.org/project/environmental-assessment-project-kabwe-zambia/. Accesses on 14.08.2015.

[5]Y. Mathee, Von Schirnding, M. Montgomery and H. Röllin Lead poisoning in South African children, The hazard is at home. Rev Environ Health; 19: 347-361, 2004.

[6]Y. Mathee, Von Schirnding, J. Levin and I. Naik. Reductions in blood lead levels among school children following the introduction of unleaded petrol in South Africa. Environmental Research 100(3):319-322, 2006.

[7] J. Nriagu, C. J. Champak., R. Naidoo and A. Coutsoudis Lead poisoning in children in Africa, II.

Kwazulu/Natal, South Africa. Sci Total Environ; 197: 1-11, 1997.

[8]S. H. D'souza, G. Menezes. Toxicology and Industrial Health, Vol. 22; 249-254, 2006.

[9] ATSDR. Lead Toxicity, Agency for Toxic Substances and Disease Registry, Department of Health and Human Services, 2005.

[10] CDC – Lead CDC'S Childhood lead Poisoning Prevention Program, 2009.

[11] R. Norman, A. Mathee, B. Barnes and L. van der Merwe, D. Bradshaw and the South African Comparative. Estimating the burden of disease attributable to lead exposure in South Africa in 2000

[12] G. W. Goldstein. Neurological concepts of lead poisoning in children. Pediatric Annals, 21 (6): 384–388, 1992.

[13] M. Smith, T. Delves, R. Lansdown , B. Clayton and P. Graham. The effects of lead exposure on urban children: the Institute of Child Health/Southampton Study. Dev Med Child Neurol Suppl. ; 47:1-54, 1983.

[14] H. L. Needleman and D. Bellinger. Studies of lead exposure and the developing central nervous system: a reply to Kaufman. Arch Clin Neuropsychol ;16:359–374, 2001.

[15] T. I. Lidsky and J. S. Schneider. Lead neurotoxicity in children: basic mechanisms and clinical correlates. Brain; 126:5–19, 2003.

[16] D. C. Bellinger and H. L. Needleman. Intellectual impairment and blood lead levels [Letter] N Engl J Med; 249(5):500–502, 2003.

[17] P. A. Baghurst, A. J. McMchael, N. R. Wigg and G. V. Vimpani. Lead exposure and intelligence in 7 year-old children, 1997.

[18] D. C. Bellinger. Supplement article: Lead. Paediatrics Vol. 113 No. 4 pp;, 1016-1022, 2004.

[19] S. Tong, E. Yasmin, Von Schirnding, and T. Prapamontol. Environmental lead exposure: a public health problem of global dimensions, 2000.

[20] L .D. MaGrant and A. I. Sors. Lead exposure and child development: An international assessment. Lancaster, England, MTP Press:119–128, 1989.

[21] United States Environmental Protection Agency National Lead Information Centre Hotline, 2010: www.epa.gov/lead/pubs/nlic.htm

[22] D. C. Bellinger. Effect modification in epidemiologic studies of low-level neurotoxicant exposures and health outcomes. Neurotoxicol Teratol; 22:133–140, 2000.

[23] K. Karin, B. Terry. Recent Developments in Low-Level Lead Exposure and Intellectual Impairment in Children. Environ Health Perspect. v.112 (9), 2004.

[24] J. S. Schneider, M. H. Lee, D. W. Anderson, L. Zuck and T. I. Lidsky. Enriched environment during development is protective against lead-induced neurotoxicity. Brain Res. ;896:48–55, 2001.

[25] S. Tong and A. Y. Lu. Identification of confounders in the assessment of the relationship between exposure and child development. Ann Epidemiol; 11:38–45, 2001.

[26] G. A. Wasserman, and P. Litvak. Methodology, inference and causation: environmental lead exposure and childhood intelligence. Arch Clin Neuropsychol ; 16:343–352, 2001.

[27] G. Winneke and U. Krämer. Neuropsychological effects of lead in children: interactions with social background variables. Neuropsychobiology; 11:195–202, 1984.

[28] WHO. Inorganic Lead. International Programme on Chemical Safety, Environmental Health Criteria. WHO Geneva, 165, 1995. blood lead levels in a lead mining area in South Africa. Environmental Research; 93: 259- 263,2003. Available: http://www.inchem.org/documents/ehc/ehc/ehc165.htm [accessed 30 March 2004].

[29]CDC. The National Report on Human Exposure to Environmental Chemicals. Lead Poisoning, 2005.

[30]Y. Schirnding, A. Mathee, M. Kibel, P. Robertson, N. Strauss, and R. Blignaut. A study of paediatric

[31]H. L. Needleman, C. Gunnoe, A. Leviton. Deficits in psychologic and classroom performance of children with elevated dentine lead levels. N Engl J Med; 300: 689-95, 1979.

APPENDICES

Appendix 1: Data Recruitment Form

Date	Community	Zone	Age	Sex	Blood Lead Levels, µg/dL
23/06/2010	Makululu	Makululu			
23/06/2010	Makululu	Moomba			
23/06/2010	Makululu	Zambezi			
23/06/2010	Makululu	Chililalila			

Appendix 2: Photo on the abandoned Kabwe lead mine

Photo 1: Health worker examining a sick scavenger at abandoned Kabwe lead mine

Photo Credit: *Blacksmith Institute*

Photo *2: Young men at abandoned Kabwe lead mine site*

Photo Credit: *Blacksmith Institute*