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Lead dust exposure and blood lead levels among workers in used battery recycling factories in Dar es salaam, Tanzania

Abstract

Background: Used Lead Acid Battery (ULAB) recycling factories[1] produce Lead, which brings health effects among workers. Lead is an environmental and occupational pollutant agent. Lead toxicity is one of the most prevalent occupational and environmental health problems in the world.[1]

Objective: The main objective of the surveillance was to determine lead exposure levels and associated health effects among workers in ULAB recycling factories in Dar es Salaam, Tanzania.

Material and Methods: This was a cross sectional study conducted in two of the ULAB recycling factories (Factory A and Factory B) in Dar es Salaam. The Socio demographic characteristics from 149 workers in the two factories were assessed. Lead exposure levels in air and blood Lead level (BLL) was measured (n=60). Inductive Coupled Plasma Optical Emission Spectrometry (ICP-AOS) used for analysis of Lead exposure level and BLL data and control measure were analysed using SPSS version 23.

Results and discussion: The arithmetic mean (AM) age was 30.56 years with standard deviation (SD) 8.66. The mean duration of employment was 82.24(69.55) and 47(57.09) months for Factory A and Factory B respectively. Geometric Mean (SD) for Pb level in air were 307.9(5.08) µg/m^3 and 242.9(1.94) µg/m^3 for factory A and factory B respectively, which were higher compared to the OEL value of 50 µg/m^{3}by NIOSH and that of 0.5µg/m^3 by WHO. The mean Blood Lead Level was 9.36 µg/dL and 17.30 µg/dL for Factory A Factory B respectively. The use of protective equipment was 2.70 % for respirators and 79.90% reported on being provided with a piece of cloth.

Conclusion: The study concludes that higher levels of lead in air was associated with the recycling processes at ULAB recycling factories. Workers in these factories had inappropriate PPE in comparison with hazards exposed. The mean Blood Lead level of the workers for factory were higher than the CDC reference value of 5µg/dL whereas at these level workers may experience health effects.

Keywords: lead dust, blood lead, exposure, battery recycling, Tanzania

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Introduction

The global battery industry is the principal consumer of lead and uses an estimated 80% of annual primary lead (mined) and secondary lead (recycled) production. Approximately 50% of global lead production is derived from recycling of lead batteries.[2] This unbroken demand for lead, rapid urbanization, and a growing vehicle fleet has stimulated the rapid growth of domestic lead recycling industries in Tanzania as well. Lead is recognized as an environmental and occupational pollutant. Lead toxicity is one of the most prevalent occupational and environmental health problems in the world.[1]

The World Health Organization estimates that 240 million people are overexposed with lead dust and 99 % of those with blood lead levels above 20 µg/dl in the developing world. A study conducted among Ethiopian automotive garage workers revealed that all lead exposed workers had BLL exceeding 10 µg/dL whereas around 47% had blood lead levels of over 20 µg/dL.[3]

Poor collection, storage, transportation and recycling processes are practices potentially expose workers to lead putting them at risk of developing lead toxicity. Lead causes numerous adverse health effects in almost all organ systems of the body, where anaemia is the classic manifestation of the toxicity.[4]

Average worker blood lead level in these factories was twice the recommended level at which workers should be removed from working around lead. Airborne exposures in these factories averages twice the Permissible Exposure Level established by US OSHA in 1979.[2]

Recycling lead acid batteries is a common practice around the world, especially in low-income countries. Many recycling facilities do not operate to good environmental and occupational standards, with consequent impacts on the health of workers and the surrounding community. The informal recycling sector operates with minimal or no occupational and environmental controls.[5] A slight rise in Blood Lead Levels were seen in the workers who did not use PPE in comparison to those who took some measures.[4]

Used Lead Acid Batteries (ULAB) recycling industries are manufacturing industries that provides employment to enormous number of Tanzanians. Lead recycling makes an important contribution to sustainable development, easing the pressure on non-renewable resources and reducing carbon emission through a simple and energy-efficient recovery process.[6]

Recycling used lead acid batteries have environmental benefits. However, tasks, primitive operations, generally deprived health, and safety practices within the ULAB Factories are associated with high lead exposures that can potential cause severe health effects among exposed employees.

This survey therefore aims at assessing the dust exposure levels and corresponding blood lead levels among workers in Lead Acid Batteries recycling factories in Dar es Salaam, Tanzania.

Battery recycling process and layout

In order for recycling process to be done, used batteries must be collected and mechanically or manually broken up to separate the sulphuric acid electrolytic solution, plastic case and the lead component parts.[7] The lead components are conveyed to the rotary furnace for smelting where required chemicals are added into the furnace and smelted for three to four hours. After smelting the slag and any other waste is removed and disposed, the molten unrefined lead is poured into trays and allowed to cool into lead blocks. All lead blocks are sent to refining furnace by using crane. The aim of the refining process is to produce lead of high purity hence requiring the addition or removal of specific trace elements in the refining kettle. Following casting of ingots through casting machine (Figure 1).

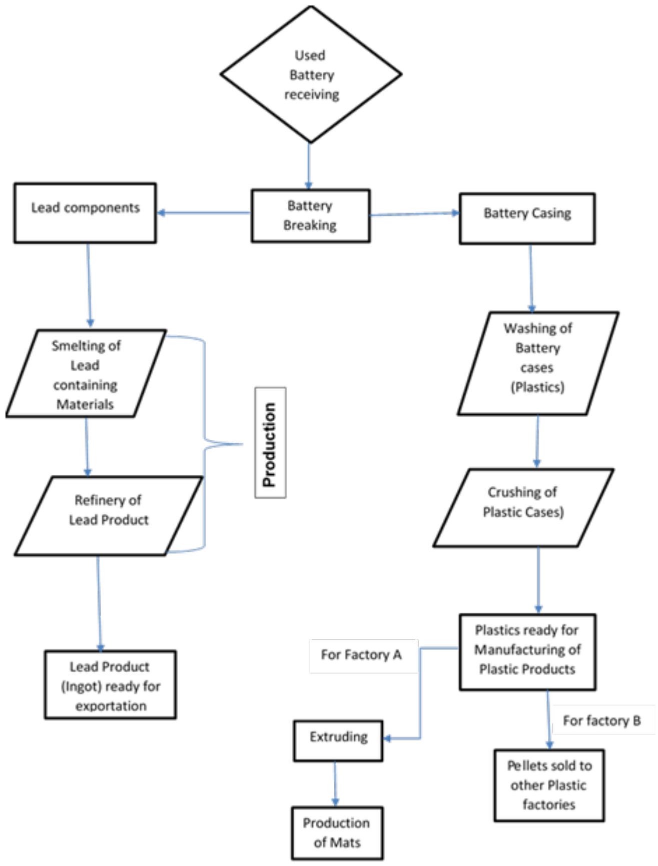

Figure 1 Used lead acid battery recycling process layout.

Recyclable plastic components in both factories washed, and shredded into pellets. In Factory A pellets are moulted and extruded to manufacture plastic products, whereas Factory B sell out their pellets to other plastic manufacturing industries.

In the workplaces the risk of occupational lead exposure exists where workers are exposed to lead and its compounds in the form of lead dust, lead fumes especially in lead smelting Factories, battery repairs and recycling units.[8]

Exposures to lead in the workplaces occur mainly through inhalation of lead laden particulates, poor personal hygiene, and ingestion of lead contaminated water and food.[4]

According to estimates made by the National Institute of Occupational Safety and Health (NIOSH), more than 3 million workers in the United States are potentially exposed to lead in the workplace.

Blood lead levels among lead acid battery recycling workers

Lead used in recycled lead acid battery industries come from lead recovered from old or used batteries. The process involved in recovering lead is crude, and is the most likely cause of unusually high exposure to lead.

Blood lead level (BLL) is the most frequently used bio indicator of recent lead exposure, the most appropriate indicator of actual (present) or previous permanent lead exposure, but also a good indicator of lead body burden.[9]

A study done in Bangladesh among workers in the Lead acid battery industries found blood lead levels to be high among those involved in acidifying section (78.70 µgm/dL), plate making process (73.57 µgm/dL) and opening and breaking of old batteries (66.77 µgm/dL).[1]

Several studies that have investigated BLLs among children living near used lead-acid battery (ULAB) recycling areas have found high BLLs in affected children.[10]

Consistent with other studies a lead-acid battery recycling factory in Kenya was found to have elevated concentrations of lead in the air and elevated blood lead concentrations among workers.[11]

Studies on blood lead levels among workers in the recycling industries in Tanzania is still lacking hence there is inadequate knowledge on the prevalence of blood lead levels.

Battery recycling process can result in the release of lead fumes and particles in the air. Studies have shown that there is high airborne lead exposure in lead-acid battery recycling facilities.[12] Air-borne lead concentrations have been shown to correlate with blood lead concentrations in workers.[11]

A study done in South Africa revealed high dust levels in smelting and refinery with mean lead in air levels above 0.15 mg/m^3. This also corresponds to the higher mean blood lead levels where as workers in the battery breaking area had the highest despite the use of inadequate Control.[13]

A review of published literature on exposures from lead-acid battery manufacturing and recycling factories in developing countries reported high airborne lead concentrations in recycling facilities, with a mean value of 367 $\mu g/m^3$ which is 7 times higher than the permissible exposure limit of 50 µg/m3 as an 8-hour time-weighted average(TWA) adopted in the USA.[5]

Material and methods

This study took place in Dar es Salaam region involving two Lead Recycling factories in Dar es Salaam. The factories named as Factory A with 104 workers and Factory B with 64 workers. The battery recycling factories involved five (5) main processes that are; collection and transportation of the batteries to a recycling facility; separation of the component parts of the batteries or dismantling; smelting and refining of the lead components, washing then shredding or melting of the plastic components.

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Study design

Cross-sectional study design involved in this survey. Quantitative technique using a structured questionnaire having closed ended questions together with a checklist to assess workplace conditions.

Sample size estimation exposure assessment

The sample size for exposure assessment i.e. dust levels, lead levels in air and blood lead levels were obtained from the observational group of the ULAB factories in Dar es Salaam. Random sample size was drawn from a group of size (N) which ensures with 90% confidence that at least one individual from the highest 10% exposures was contained in the sample. For the matter of this study, NIOSH sample determination for similar exposure groups was adopted.[14]

Sample size determination for assessment of health effects

According Ahmad, et al.,[1] the prevalence of workers with high blood lead levels is 50% .The number of population in two of the ULAB factories workers was164 therefore the number of sample size for assessment of health effects among Lead battery recycling workers was obtain through OpenEpi Version 3, open source calculator.[15]

Therefore,

Population size (for finite population correction factor or fpc) (N): 168

Hypothesized % frequency of outcome factor in the population (p): 50%+/-5

Confidence limits as % of 100(absolute +/- %) (d): 5%

Design effect (for cluster surveys-DEFF): 1

Sample size n = [DEFF*Np (1-p)]/ [(d²/$Z^2_{1-\alpha/2}$*(N-1) +p*(1-p)]

For a 95% confidence interval, the number of sample size is 118

This sample size adjusted for 10% non-response rate:

$$n = 118\frac{1}{R}$$

$$n = 131$$

Therefore, the number of sample size for this study was 131

Sampling procedure for assessment of health effects

Probability sampling was done, where sample were obtained from two ULAB recycling factories that are clusters in this case. Proportional sampling was done from each cluster where the probability of a unit to be selected from the cluster was taken to be proportional to the ultimate unit, where by a larger cluster will have a high chance of selection and a small cluster will have a small chance of selection.

Therefore, the number of sample size were calculated as follows; -

i. The number of workers from Factory Aare 104,

Therefore, the number of sample size for ULAB Factory A will be

$$\frac{104}{168}\times 131 = 85$$

$$(n) = 81$$

ii. The number of workers fromFactory B are64

Therefore, the number of sample size for ULAB Factory B will be

$$\frac{64}{168}\times 131 = 50$$

$$(n) = 50$$

Dust and lead in air sampling procedure

Dust and Lead in air measured by personal dust samples that were collected from the two factories. Lead in air was measured from dust samples collected for the whole working shift of 8 hours. Personal total dust samples were collected from breathing zone of the workers. Pre weighed PVC filters, with pore size of 8μm and diameter of 35mm mounted on a two-piece plastic cassette with 4mm orifice, were used to collect dust samples. The filter cassettes connected to SKC Pumps operated at a flow rate of 2l/min.

Dust sample analysis

Dust sample analysis done at MUHAS Physiology Laboratory. The filters on the cassettes were desiccated for 24 hours in pre and post sampling using a Mettler Tonido weighing scale. The weighing balance was calibrated before taking the measurements. Using gravimetric analysis, the weight of dust on the filter was determined. The weight in milligrams (mg) of dust on the filter and the volume based on the 2l/min flow rate and the sampling time of 8 hours. The dust concentration was in mg/m3.

Determination of Lead in dust by using ICP-OES

Lead (Pb) was analysed in suspended particulate matter collected from ambient Air, PVC membrane filters. The dust sample was digested by acid, filtered and analysed by ICP-OES. The filter was place into the conical flask where 10 mL of extraction solution (1.5% HCl, 5.55% HNO3) was added. The flask placed onto the hotplate for digestion for 2.5 hours at 85°C (±5°C). After 1.5 hours of extraction, 1.8 mL of $H_2O_2$was added and the sample left to effervesce for 0.5 hours. An additional 1.8 mL of H_2O_2 was added after 2 hours of extraction and allow effervesce again for 0.5 hours. The samples were allowed to cool. Then 20 mL of distilled water added and the sample was left standing for 0.5 hours. This allowed the acid to diffuse from the filter into the rinsing water. The diluted sample was filtered to a final volume of 50ml.The extracted solution was analysed in Induced Couple Plasma Optical Emission Spectrometer (ICP-OES) for determination of Lead. Results were in mass/ weight of the dust sample (mg/m^3).

Blood sample sampling and determination of blood lead levels

Blood samples (5mL) was drawn out from each respondent participating in the study for blood lead level estimation using Dark Blue top with Lavender Stripe (EDTA, metal free) tube. To avoid contamination, powder less gloves were being used. Blood was drawn directly into the tube with the use of a butterfly needle by vacutainer technique. Blood samples labelled with appropriate coding, sent to GCLA for analysis while in cooler boxes. Upon receipt, samples were frozen at –20°C until time for analysis.[16]

Blood lead level was quantified by inductively coupled plasma optical emission spectrometry (ICP-OES), Model iCAP 7000, Thermo Scientific). The collected whole blood samples were homogenized by vortex for 2 min and 1.0 ml of whole blood samples were drawn by pipette into 10ml falcon tube. 9 mL of 0.1M nitric acid was added into falcon tube and mixture solution was mixed by vortex for 2 min. The blood solution was ready for (ICP-OES) analysis. Lead was 0.005mg/L. For quality assurance and quality control, the standards and blanks were run after every 10 samples, to assure the working of instrument with 95% accuracy. Reference: Determination of lead in plasma, whole blood, and urine by ICP-MS and the relationships among the three exposure indices.[17]

Data analysis

Collected data was cleaned, entered in the computer and then analysed using Statistical package for social sciences (SPSS) version 23. Continuous variables were summarized into descriptive statistics such as means, standard deviations and range while categorical variables were summarized into proportion. Chi-square test were used to determine the level of association between variables at 95% confidence level, p-value of less than 0.05 was considered statistical significant.

Ethical clearance

Ethical clearance was obtained from Institutional Research Board of Muhimbili University of Health and Allied Sciences. Informed consent form in Kiswahili explaining the aim, purpose and contents of the surveillance was used. The participants were required to give a written consent before participating in the study. The Lead recycling factories A and B names were omitted to maintain confidentiality of the findings. Codes were used for identity the study participants instead of names to assure confidentiality.

Results

Socio-demographic characteristics

This study enrolled 149 workers from two lead acid battery-recycling factories (Factory A and Factory B) in Dar es Salaam. The arithmetic mean (AM) age was 30.6 years with standard deviation (SD) 8.7. Eighty-seven workers (58.4%) were aged between 18 to 30 years. One hundred and forty-four (96.6%) were male and 5(3.4%) were female. Out of 149 workers, 68(45.6%) had primary education, 63 (42.3%) had secondary school education, 12 (8.1%) had tertiary education and 6 (4%) had never been to school. In this study 12(14.10%) and 9(14.10%) workers reported to have ever smoked for Factory A and Factory B respectively. In Factory A 10(11.80%) and in Factory B 6(9.40%) of workers reported to be current smokers. The mean duration of employment was 82.24(69.55) and 47(57.09) months for Factory A and Factory B respectively **(Table 1)**.

Distribution of workers in the working sections

Factory A has workers in all working sections, while Factory B has workers in Initial battery recycling process and production section. Majority of workers involved in the study were from initial battery recycling section (Factory A 12(14.1%) and Factory B 40(62.5%)). In Factory A, 23(27.1%) were from maintenance section and 16(18.8%) were from production section. In Factory B, 22(34.4%) were from production section (Table 2).

Total dust and lead exposure assessment among workers

The geometric mean (GM) and geometric standard deviation (GSD) for dust exposure level in air in Factory A and Factory B was 2.87(3.56) mg/m^3 (n=17) and 1.52(1.81) mg/m^3 (n=17), respectively. The GM for lead exposure level in air for Factory A and Factory B was 307.91(5.08) μg/m^3 (n=17) and 242.86(1.94) μg/m^3 (n=17), respectively (Table 3).

Distribution of dust levels for among workers in Factory A and Factory B

The figure shows the distribution of samples by identification number taken in two of the ULAB factories divided by the vertical line (Figure 2).

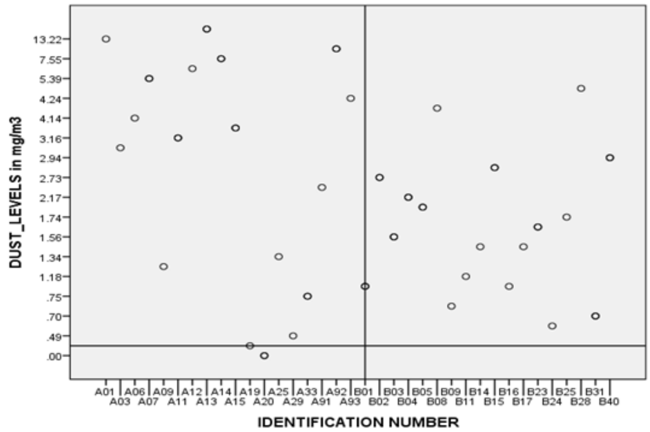

Figure 2 Distribution of dust levels among workers Factory A and Factory B.

Dust exposure level as per work section (mg/m^3)

Dust exposure level in Factory A were higher in production section with mean 5.51(2.25) mg/m^3 while in Factory B dust exposure levels were higher 4.19(1.00) mg/m^3 in the environment section. Lead exposure level were high in the production section for both factories with mean (SD) 549.66(4.78) μg/m^3 and 288.18(1.44) μg/m^{3}in Factory A and Factory B respectively (Table 4).

Correlation between total dust levels and lead level in air

There is a significant association between the levels of total dust and lead in air where; p=0.002, Pearson Correlation coefficient (r= 0.516) and 26.6% of the variation of lead in dust is attributed by variation in total dust levels (Figure 3).

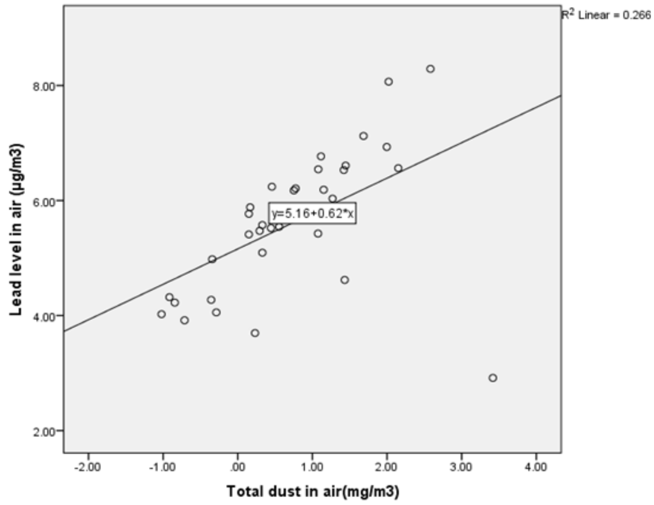

Figure 3 Correlation between total dust and Lead level in dust in air.

Blood Lead Level among workers in Factory A and Factory B

Production workers in factory A had high BLL compared to other section (9.83(2.19)) while the lowest BLL was among plastic workers.

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In Factory B workers in initial battery recycling process had the highest mean BLL compared to other sections (18.85 (2.52)). Workers in Factory B had higher mean BLL compared to workers in Factory A (Table 5).

Table 1 Socio-demographic characteristics of the study population (n=149)

Characteristics	Factory A n=85	Factory B n=64	All
Age (AM (SD)) years	32.15(8.93)	28.44(7.85)	30.56(8.66)
Age group (n (%))			
18-30	45(52.90)	42(65.60)	87(58.40)
31-40	19(22.40)	15(23.40)	34(22.80)
41-50	16(18.80)	6(9.40)	22(14.80)
51 and above[a]	5(5.90)	1(1.60)	6(4.00)
Sex (n (%))			
Male	82(96.50)	62(96.90)	144(96.60)
Female	3(3.50)	2(3.10)	5(3.40)
Marital status (n (%))			
Single	40(47.10)	32(50)	72(48.30)
Married	43(50.60)	29(45.30)	72(48.30)
Divorced/Separated	2(2.40)	2(3.10)	5(3.40)
Education Level (n (%))			
Never been to school	2(2.40)	4(6.30)	6(40)
Primary	37(43.50)	26(40.60)	68 (45.60)
Secondary	37(43.50)	26(40.60)	63 (42.30)
Tertiary	9(10.60)	3(4.70)	12 (8.10)
Mean Duration of employment (months)	82(69.55)	47(57.09)	71(85.19)
Smoking habit (n (%))			
Ever smoked	12(14.10)	9(14.10)	21(14.10)
Current smoke	10(11.80)	6(9.40)	16(10.70)
Alcohol consumption (n (%))			
Ever consume alcohol	16(18.80)	16(25.00)	32(21.30)
Current alcohol consumers	16(18.80)	13(20.30)	29(19.30)

[a]Two workers were above 60 years

Table 2 Number of workers as per working sections, n=149

Working Section	Factory A n (%)	Factory B n (%)	Total n (%)
Initial battery recycling process	12(14.10)	40(62.50)	52(34.90)
Production	16(18.80)	22(34.40)	38(25.50)
Plastic	19(22.40)	1(1.60)	20(13.40)
Cleaning	4(4.70)	1(1.60)	5(3.40)
Maintenance	23(27.10)	0	23(15.40)
Store	11(12.90)	0	11(7.40)
Total	**85(57.00)**	**64(43.00)**	**149(100.00)**

Table 3 Dust exposure levels and lead levels in air among workers

Parameters	Factory A		Factory B	
	N	GM (GSD)	n	GM (GSD)
Dust exposure level (mg/m^3)	17	2.87(3.56)	17	1.52(1.81)
Repeated Dust exposure level (mg/m^3)	7	4.82(4.27)	7	1.42(2.81)
Lead exposure level in dust ($\mu g/m^3$)	17	307.91(5.08)	17	242.86(1.94)
Repeated measurements Lead exposure level in dust ($\mu g/m^3$)	7	459.99(4.15)	7	113.85(7.15)

Table 4 Dust and Lead exposure level as per work section (mg/m^3)

Factory	Section	n	GM(GSD) Total dust levels in air(mg/m3)	GM(GSD) Lead levels in air(µg/m3)
Factory A	Initial battery recycling process	2	0.76(2.23)	127.63(2.42)
	Production	12	5.51(2.25)	549.66(4.78)
	Plastic	2	0.61(1.35)	53.86(1.10)
	Maintenance	1	0.36(1.00)	55.91(1.00)
	Total	**17**	**2.87(3.56)**	**307.91(5.08)**
Factory B	Initial battery recycling process	7	1.10(1.97)	220.79(2.46)
	Production	9	1.74(1.43)	288.18(1.44)
	Cleaning	1	4.19(1.00)	101.46(1.00)
	Total	**17**	**1.52(1.81)**	**242.86(1.94)**

Table 5 Blood Lead level among workers per section

Factory	Section	n	Mean BLL(SD) (µg/dL)	n	Mean Repeated BLL (SD) (µg/dL)
Factory A	Initial battery recycling process	7	9.24 (1.36)	4	7.71(2.05)
	Production	9	9.83 (2.19)	6	6.34(3.15)
	Plastic	2	7.73 (2.18)	1	8.49
	Maintenance	1	9.28		
	Total	**9**	**9.36 (1.85)**	**11**	**7.03(2.63)**
Factory B	Initial battery recycling process	6	18.85 (2.52)	5	15.79(4.10)
	Production	8	16.41 (0.89)	4	13.70(1.40)
	Cleaning	1	15.23		
	Total	**5**	**17.30 (2.11)**	**9**	**14.86(3.22)**

Discussion

This study assessed exposure and effects of lead among 149 ULAB recycling workers in two factories in Dar es Salaam. Of these 86.6 % workers reported to have experienced at least one lead poisoning symptom. The most reported symptoms were joint pain and body fatigue. Personal total dust levels measured in the working section had a GM (GSD) of 2.87 (3.56) and 1.52 (1.81) mg/m^3 in Factory A and B, respectively. Lead level in air was 307.91(5.08) µg/m^3 in Factory A and 242.86 (1.94) µg/m^3 in Factory B. Workers in Factory B had higher mean BLL of 17.30(2.11) µg/dL compared to Factory A 9.36 (1.85) µg/dL. During a walk through survey inadequate ventilation, poor control measures as well as inappropriate use of PPE observed.

Dust and lead exposure level

The findings of this study show workers are exposed to high lead dust levels with geometric mean of 2.87(3.56) mg/m^{3}for factory A and 1.52(1.81) mg/m^3 for Factory B. The dust correlated with exposure levels of lead whereas the high the dust in air the higher is the lead level in air. Most of the studies conducted presented the level of lead in the air but not the level of dust sampled. In light of high sample analysis cost sampling few samples and modelling the exposure based on dust levels in these factories will reduce the costs for laboratory analyses. However, more studies are needed to ascertain the positive correlation between dust and lead levels in air.

The current study shows that Lead exposure level in air was 307.9(5.08) µg/m^3 for factory A and 242.9(1.94) µg/m^3 for factory B. These levels were higher compared to the occupational exposure limit value of 50 µg/m^3 indicated by NIOSH This exposure was found to be lower compared to a study done in Kenya in battery recycling factory where the mean exposure was 427±124µg/m^3.[11] Flame atomic absorption spectrophotometer (FAAS) was used for determination of lead in the Kenyan study, which could have different detection capacity as compared to ICP- EOS that was used in the current study. Another study done in 2003 in Thailand found the exposure level slightly lower than the one in this study where mean exposure level was reported to be 0.2 mg/m^3.[18] This difference could be due to different process as the Lormphongs' study was done in battery manufacturing. However, lead determination method was not mentioned which could also introduce differences due to varying detection limits**.** Also, a study done in South Korea showed lower exposure levels compared to the current study, where the mean exposure level was 0.464 ± 0.154 mg/m^3 (Kim et al., 2002).

Blood Lead level among workers in ULAB factories

The mean blood Lead level for Factory A was 9.36 µg/dL and for Factory B was 17.30 µg/dL, all these are below the U.S. Occupational Safety and Health Administration's permissible exposure limit of 30 µg/dL in blood. BLL more than 30 µg/dL are associated with adverse health effects. This is different with the study done in Kenya on Lead acid battery recycling Factories[11] where the mean blood Lead level for battery Factories was 59.40 µg/dL. In the Kenyan study there was a high correlation between blood lead levels and the concentration of lead air[11] which was not observed in our study. This could be due to differences in determination methods used between the two studies[19] recommend the medical removal of Pb-exposed workers, if a single BLL concentration exceeds 30 µg/dL.

Reported lead poisoning symptoms

Battery recycling workers exposed to lead and report to have experienced health symptoms. The most reported symptoms were body fatigue and joint pain. It has been evident that people with lead poisoning experience painful joints and body fatigue.[20]

Recycling lead acid batteries is a common practice around the world, especially in low-income countries.[21] Many recycling facilities do not operate to good environmental and occupational standards, with consequent impacts on the health of workers and the surrounding community. The informal recycling sector operates with minimal or no occupational and environmental controls.[5] A slight rise in BLL was seen in the workers who did not use PPE in comparison to those who took some measures.[4]

Taking measures related to occupational health as hygiene and safety at the work place can improve the existing poor working environment and prevent the lead toxicity.[3]

Engineering Controls, Administrative control and personal protective equipment have been identified as the main ways to control hazard at the ULAB recycling facilities. In addition to this, implementation of proper work practices such as hand washing, wearing and cleaning of respirators together with proper hygiene are among the work practices that minimize workers' exposure to lead.[6]

Lead acid battery recycling industries in Dar es Salaam Tanzania have not invested much on improving working environment and environmental conditions like Ventilation, temperature and lighting which accelerate the absorption of lead in the body. Improved ventilation at workplaces would help in lead poisoning prevention by diluting the air contaminants.[13] About 59% of workers reported to work in poor ventilated environment and 45% working in hot environment. These reported poor working conditions are supported with observation where inadequate engineering measures were prevailing in both Factories.

Multiple sources of fugitive dust emission were noted. In Factory A where ashes from the emission pipes which was sometime drawn by air to the working area, coal crushing was done inside Factory A. The total dust levels for Factory A was 3.18mg/m^3 this is significantly higher as compared to Factory B 1.56mg/m^3; these results are in line with the study done by WHO.[22] All these activities were conducted within the Factory At Factory A, whereby they would be arranged to be performed at different locations. Maintenance activities involving welding of furnace parts and construction of furnace lining, which is conducted next to supervisors' offices and lead ingot store, expose other workers unnecessary to noise and welding fumes while they are exposed to lead though their work could be accomplished without being exposed to lead.

PPE use among workers in Lead acid battery recycling factories

In this study results show that 90.60 % of workers reported on the use of PPE however half the population in Factory A had not received training on the use of PPE. The mean dust exposure level in Factory A was 3.18mg/m^3 and 83.50% of workers reported at least one lead poisoning symptom. This finding is similar to a study by Ahmad, et al.,[1] which supports that inappropriate use of PPE due to inadequate training is a contributory factor to the exposure of lead and its toxicity.

Employees in both factories reported to wear with several protective gears such as gumboots, masks, gloves, helmet, overall, hearing protection and respirator. Overall, in both factories only 2.70 % reported to wear respirator while 79.90% reported to use cloth masks. Use of respirator has proven to reduce the average inhaled lead concentration.[11,23] The fact that in the present study majority of the workers were not using respirator indicates possible exposure to lead dust.[24,25]

Potential limitations and mitigations of the study

Cross sectional study: where we analysed exposure and effects at the sometimes. This limitation mitigated by assessing exposure retrospectively based on duration of work and use of mean exposure for varying parameters, the effects of weather was assessed.[26–33]

Conclusion

The study concludes that there are higher levels of lead in air above 50µg/m^3 (ACGIH) in the ULAB recycling factories. Workers in these factories are provided with inappropriate PPE that were not protecting them. Blood Lead Level of the workers is higher compared to WHO guideline of 10ug/dL where at these level workers may experience adverse health effects. There is a need to conduct health effect study to establish the magnitude of health effects and control mechanism.

Acknowledgments

Therefore, Workers Compensation Fund (WCF) in collaboration with the department of Environmental and Occupational Health-Muhimbili University of Health and Allied Sciences (MUHAS) decided to undertake this survey to evaluate lead exposure among workers in Lead Acid Batteries recycling Factories in Dar es Salaam and thereafter implementing interventions to ensure workers protections. Norhed through the dust pumps, filters and Metlo Tonido weighing equipment installed at MUHAS Laboratory. WCF Tanzania funded the study.

Conflicts of interest

The authors declare there is no conflict of interest.

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