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Full Length Research Paper

Lead Acid Battery Recycling in the Current Tanzania Industrialization Drive: Challenges and Opportunities

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ABSTRACT

Advancements in automotive technologies, Information and Communications Technology and renewable energy technologies have increased the use of lead acid batteries as a source of portable and rechargeable energy. This has considerably increased the number of spent batteries with adverse effects on the environment and human health; which calls for recycling of spent batteries. This work was conducted to investigate challenges facing the formal business of recycling spent batteries and potential manufacturers of new lead-acid batteries in Tanzania. The work involved collection of information from key stakeholders such as collectors, dealers, Tanzania Revenue Authority and recyclers. It was found out that about 2 million units of used batteries are available in Tanzania annually; weighing a total of about 8,440 tonnes. At the moment of conducting this work, only two recycling plants were in operation: Ok Plast ltd and Gaia Eco-Solutions (T) Ltd. The two operational ULAB recycling plants process about 6,000 tonnes per year. Despite the large number of spent batteries available annually, the amount received by the two recycling plants is far less than the number of spent batteries available in country. Gaia plant processes about 3,600 tonnes of spent lead batteries per year while OK-Plast is only about 1,500 tons/year. The study revealed existence of illegal exportation of ULAB which is against national Regulations and the Basel International Convention. A number of challenges and opportunities have been discussed. Despite of the challenges, the local ULAB recycling industry in Tanzania is encouraged to explore opportunities of manufacturing new batteries. A number of recommendations have been provided; however, enforcement of the export ban of used Lead Acid Batteries has been stressed.

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INTRODUCTION

Lead acid battery, which was invented in 1859 by the French physician Gaston Plant, is the first rechargeable battery to be used commercially. Lead acid battery (LAB) is produced in a variety of capacities, sizes and designs. Despite other batteries that have been marketed, lead acid battery remains the technology of choice for automotive and industrial sectors (UNEP and the Secretariat of the Basel, 2003).

The LAB is mainly used as power starter in cars, trucks, buses, boats, telecommunication towers, trains, etc., all over the world due to its relatively cheap way of stowing energy (UNEP and the Secretariat of the Basel, 2003). In recent years the development of solar panel has become much cheaper leading to an enormous boost in its application especially in rural areas where the electric grid is unavailable. Almost all solar applications contain lead acid batteries within for energy storage (Dufo-López *et al*., 2021). When the battery lifetime reaches its end, is referred as a spent battery for the application it was designed for. Due to widespread use of the lead acid batteries, production of the spent batteries has increased significantly leading to potential environmental contamination, human exposure and significant public health problems (AGENDA, 2016; Wani *et al*., 2015). It is estimated that 65% of the lead acid battery is lead which is a naturally occurring toxic metal; hence, when the battery lifetime reaches its end, it is important that proper collection and recycling takes place (Fisher *et al*., 2006). So far studies on spent/used lead acid batteries (ULAB) generation rate in Tanzania are limited. Furthermore, determination of accumulation rate of the ULAB to the environment is difficult since there is an increase in scrap collectors.

Of the recent, there have emerged recyclers of the ULAB such as OK Plast Ltd. (handles 280 – 300 tons per month), Gaia Eco Solution (recycles 15 – 20 tons per day), Gama Metal (handles 10 tons per day) and other unscrupulous traders who are said to be exporting used lead acid batteries outside Tanzania against national regulations and the Environmental Management (Hazardous Waste Control and Management) Regulations, 2019 (AGENDA, 2016; URT, 2019). It is through this observation this particular study is intended to address, which if left unattended it would jeopardize the formal business of recycling ULAB and potential manufacturing of new lead-acid batteries in Tanzania. Studies reporting spent/used lead acid batteries (ULAB) recycling rate in Tanzania are not available. Few studies on ULAB recycling in Africa including Tanzania have been previously reported (AGENDA, 2016; CREPD, 2015; Manhart *et al*., 2016; Tür *et al*., 2016). However, most of these studies focused on the adverse impacts of recycling ULAB on the environment and human health. Tür *et al*., (2016) estimated the volume of ULAB generated in various African countries including Tanzania based on the available data of registered passengers and commercial vehicles only which couldn't give an actual ULAB generation rate. This study aims to establish the national demand of new batteries and available quantity of spent batteries per year. These data will be used in mapping the business potentials and challenges in collection mode of spent batteries, proper methods for servicing, recycling and environmentally safe method of disposing them

THEORY, LEGAL AND POLICY FRAMEWORK GOVERNING BATTERY RECYCLING

Recycling Process of Spent Lead Acid Batteries

Spent lead acid battery recycling refers to the process of reclaiming the major useful components of batteries such as lead metal and plastics. These components are re-used as raw material to manufacture new lead acid batteries. Around 98% of the material in each battery is recycled (Thornton *et al*., 2001). Most of the lead produced comes from recycling and it accounts for over 60% of the world lead consumption (Besser *et al*., 2009). Some of the importance of recycling these batteries includes:

- economical gain due to low cost used to recycle lead metal compared to producing lead from mining operations,

- conservation of natural resources through minimal use of new raw material when manufacturing a new battery,
- minimizing adverse effects to human beings, animals, and environment when the used Lead Acid batteries are disposed to the environment (ABRI, 2014).

After receiving the ULABs at the recycling industry, the acid is drained and collected in a reservoir before breaking. A number of breaking systems for ULABs is available ranging from manual breaking which is done by few workers using primitive tools such as axes to complicated cutting machines like Roll crushers and Hammer mill. Breaking allows separation of lead bearing materials from the casings. The casings get cleaned and shredded by shredders. Pieces obtained from shredding are placed in a tank filled with liquid for sorting (wet screening). The sorting process is based on the density difference whereby the lighter materials float (hard rubber and plastic) and the denser materials sink (lead). The liquid wash is collected into acid reservoir (settler). After this separation, the plastic materials can be further separated into polypropylene and plastic and either shipped to plastic recyclers or used on-site as fuel supplement. The acid can either be (a) neutralized for disposal, or (b) treated to produce other chemicals like sodium sulphate or calcium sulphate for other industrial applications, or (c) reused on-site for other applications. The metallic lead from the separation process is re-melted, refined and cast into ingots of various shapes and sizes. Ingots can either be sold locally or exported to the battery and Electrical cable manufacturers (ABRI, 2014).

Figure 1 illustrates the different units involved for flow of breaking and separation process. The metallic lead from the separation process is re-melted, refined and cast into ingots of various shapes and sizes. Ingots are sold and export to the battery and Electrical cable manufacturers.

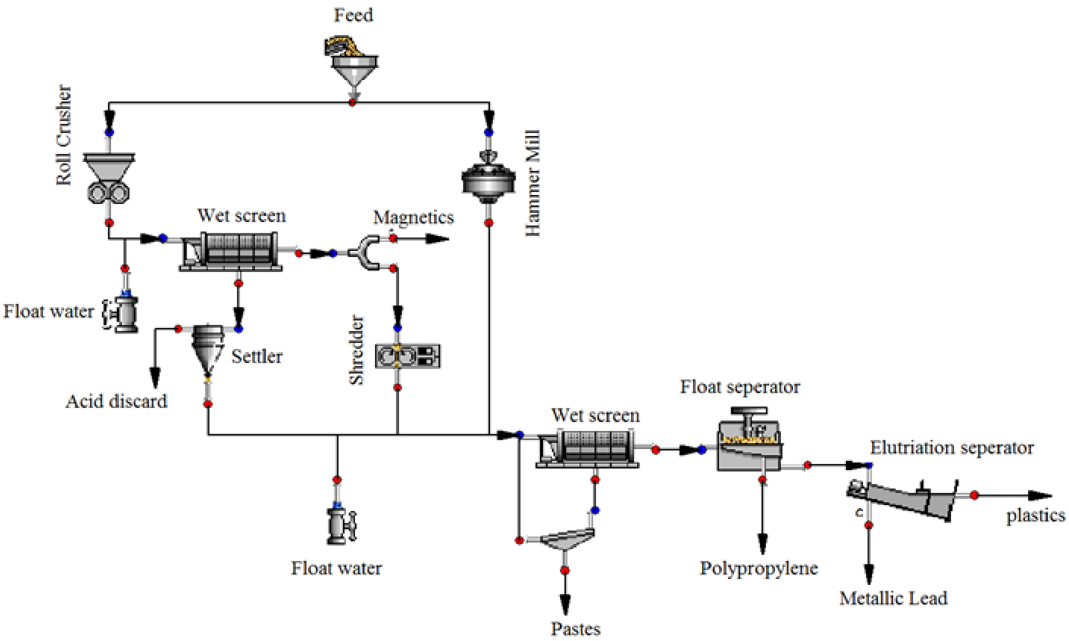


Figure 1: General flow of breaking and separation process.

Legal and Policy Framework Governing Battery Recycling

Battery recycling is governed by a number of regulations and legislation throughout the whole process which are intended to ensure sound environment for safe storage, handling, transportation and recycling of ULABs. There is various governing legislation that are implemented from national, regional and international levels such as individual country legislation to European Union.

National Laws

In Tanzania, the National Environmental Management Council (NEMC) provides regulations and legislation on the sound management of environment including the management of hazardous wastes. This is stipulated in the Environmental Management (Hazardous Waste Control and Management) Regulations, 2019 (URT, 2019). The regulations clearly describe the legal framework and responsibilities of each stakeholder on management of hazardous wastes. Further, the Tanzania Revenue Authority (TRA) under Section 70 of East African Community Customs Management Act, 2004 (The of East African Community Secretariat, 2017) prohibits the export of used automobile batteries, lead scrap, crude and refined lead, and all forms of scrap metals.

International Convention

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal is an international treaty that deals with control of movement of hazardous wastes between nations (UNEP and Secretariat of Basel Convection, 1989). It was designed in 1989 and effectively started in 1992. Another international control of hazardous wastes is the Bamako convention on the Ban of Import into Africa and the control of Trans-Boundary Movements of Hazardous Wastes within Africa (Organization of Africa Unit 1991). Tanzania is one of the countries that are part and comply with the Basel convention and Bamako convention.

In all the conventions the ULAB is categorized as toxic waste and hence their movements are subjected to the international treaties. The Basel convention provide guidelines and legislation that a member country should comply when handling hazardous wastes such as used lead acid batteries. The convention describes environmentally sound collection, transporting, breaking, recycling and exporting.

Besides the Basel and Bamako conventions, there are other instruments covering the transportations of hazardous wastes. These include:

- Recommendations on the transport of dangerous goods (Secretariat of the UNECE, 2019);
- Technical instructions for the safe transport of dangerous goods by air (ICAO, 2017 – 2018);
- International Maritime Dangerous Goods (IMDG) Code (IMO, 2018);
- United Nations Resolution on Traffic in Toxic and Dangerous Products and Wastes (UN General Assembly 44th sess.1989);

MATERIALS AND METHODS

Research Design

The methodology was both qualitative and quantitative in nature. Both descriptive and diagnostic research designs were adopted. It involved the literature survey, interviewing main stakeholders (Dealers, collectors, and recyclers) one at a time using questionnaires; collection of quantitative data from TRA; analysis of data and interpretation.

Study Area and Sampling

Our study employed a purposive sampling technique. Purposeful sampling is widely used in qualitative research for the identification and selection of information-rich cases related to the phenomenon of interest. In our case where the population of interest is small and the actual population size is unknown, purposive sampling enabled us to make the most out of our sample by getting better insights and more precise research results. Purposeful sampling enabled us also to obtain information and knowledge from the experts and people experienced in ULAB collection and recycling.

Dar es Salaam and Mwanza were chosen purposefully among the regions in Tanzania because these are the largest cities in Tanzania and having relatively higher population, more economic activities and higher number of cars and machineries. In both regions dealers/collectors and recyclers that are popular in ULAB collection and recycling, respectively were purposefully interviewed. In Dare es salaam the dealers/ collectors from Temeke, Tabata, Tegeta and Mwenge wards were selected; and in Mwanza the dealers/ collectors from Mabatini and Nyakato wards were selected.

In each selected ward all the best known ULAB dealers and collectors were identified, every identified dealer/collector were selected for the interview. However, most of the dealers in Dar es Salaam and Mwanza region could not provide full cooperation during data collection. This study considered only participants who gave full cooperation. Table 1. shows the number of identified dealers/collectors with corresponding participants in each ward.

Table 1: Total number of Dealers/Collecters that participated in this study

Selected Wards	No. of Identified Dealers/Collectors	No. of Interviewed Dealers/Collectors
Temeke	3	3
Tabata	1	0
Tegeta	2	0
Mwenge	3	2
Keko	3	0
Buguruni	2	0
Mabatini	1	0
Nyakato	1	0
Total	**16**	**5**

8 ULAB recyclers were identified using dealers/collectors' responses. All identified ULAB recyclers were selected for the study: Gaia Eco Solution, Steelcom, Gama Metal, OK Plast Ltd, "Kwa Mzungu", "Kwa Mpalestina" and Kamdhenu located in Dar es Salaam and NADAKA Industrial Products ltd (NIDL) located in Mwanza. However, only Gaia Eco Solution was willing to be interview and provided full cooperation. NADAKA Industrial Products ltd (NIDL) participated in the interview; however, couldn't provide all the required information since it was still at the feasibility stage of recycling. Therefore, in terms of recyclers only 2 respondents were considered for the study.

Data Collection

Two questionnaires were developed to extract information from dealers/collectors and recyclers. This is due to the fact that the kind of information required for each group were different.

Dealers/collectors were expected to provide information about collection commencement date, collection rate, collection capacity, purchasing procedure, source of ULABs, buying price, selling price, selling rate, selling procedure, customers of collected ULAB, challenges of ULAB collection and handling. Recyclers were expected to provide information about recycling commencement date, recycling rate from 2013- 2017, ULAB collection procedure, recycling capacity, customers of recycled products, end products of recycling and challenges of recycling.

Data for all imported cars, machineries and stand-alone batteries in a period between 2012 to 2016 as well as between 2002 - 2017 were collected from TRA headquarters. The estimation of quantity of used lead acid batteries available in the country was carried out by using Tür *et al*., (2016) method.

RESULTS AND DISCUSSION

Tanzania is among the countries that uses LABs and recycles the batteries when they reach the end of their designed life. The design life of lead acid battery is relatively low (Dufo-López et al., 2021) leading to high availability of used ULAB.

The rate of recycling in Tanzania has not been clearly established and there has been no enough documentation of the key stakeholders, recycling tonnages and export of components of lead acid batteries or manufacturing new batteries within Tanzania. This section presents the work that establishes the situation regarding the recycling process, collection, and transportation of the ULABs or its components in Tanzania using data gathered by the researchers from the stakeholders and the use of secondary data available in the literature. The data were obtained from Tanzania Revenue Authority (TRA), recyclers, retailers and agents collecting lead acid batteries and other scrap metal such as steel and aluminium. Companies that are involved in recycling, supply of ULABs to the recyclers were identified; however, others were in the feasibility stage of recycling ULABs. Some of the companies and individual dealers provided data for the survey and others did not provide information.

Quantity of Used Lead Acid Batteries in Tanzania

Figure 2 shows the total weights of stand-alone batteries imported for the year 2012 – 2016. The graph was plotted using data collected from Tanzania Revenue Authority. There is no significant variation on the total weight of stand-alone batteries imported from 2012 to 2016 except for the year 2014 where the value is relatively high. The same trend can be observed in imported machines presented in Figure 3, whereby the total number of imported machines is relatively high for the year 2014. The increase in importation rate for the year 2014 requires another investigation. Studies on the Lead acid batteries importation rate are very limited. TAREA (2016) investigated importation of lead based solar batteries in Tanzania from 2014 to 2016.The findings of this study doesn't show a pattern for comparison.

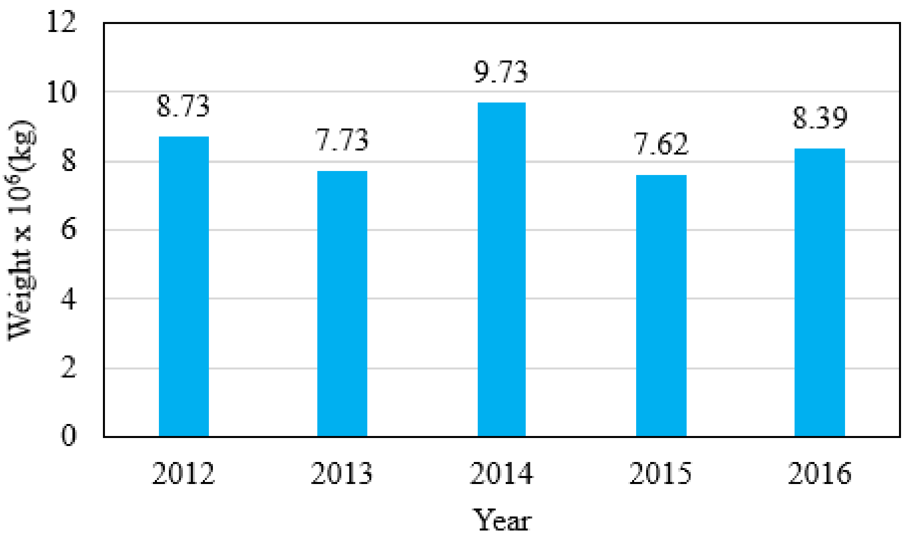
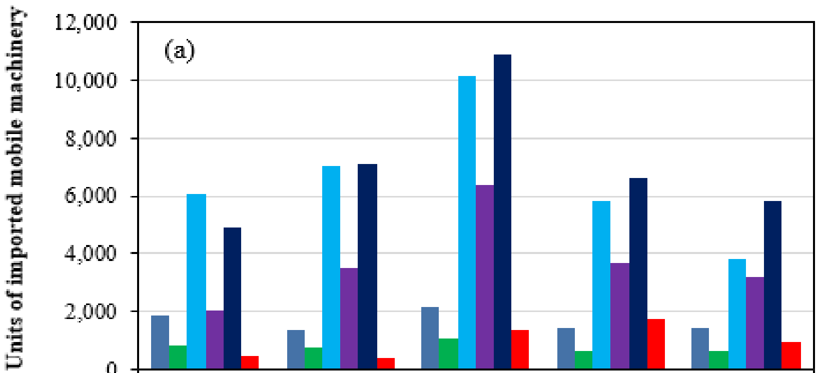


Figure 2: Imported stand-alone batteries for the year 2012 – 2016.

The total number of various mobile machineries imported for the year 2012 – 2016 are shown in Figure 3. For clear viewing, mobile machineries with imported units less than 11,000 per year are presented Figure 3(a) while mobile machinery with imported units greater than 11,000 per year are given in Figure 3(b). From these figures, two trends that is before and beyond 2014 can be observed.

Before 2014, a considerable increase in imported mobile machinery units *(mainly light load vehicles, heavy load vehicles, heavy passenger vehicle, light passenger vehicles, and motorcycle*) can be observed. For example, the light load vehicles and heavy load vehicles in 2012 were 4,913 and 6,055 whereas in 2014 were 10,858 and 10,124 respectively. Beyond 2014, a continuous decrease in the number of mobile machineries highlighted above can be observed. From the values reported in 2016, the light load vehicles and heavy load vehicles in 2016 decreased to 5823 and 3829, respectively. The reason for the increase or decrease in the imported mobile machineries requires another investigation; however, the similar pattern can be observed in the Tanzania economic growth reported by World Bank (2021). This pattern may be linked to transition in leadership in two forms: a) individuals and private institutions – from 2012 – 2014 there was a predictable business environment led to the increase in purchasing confidence while from 2014 – 2015 there was an unpredictable business environment due to 2015 leadership transition, led to the decrease in purchasing confidence, b) public institutions – cost cutting measures which was introduced after 2015 leadership transition, led to the decrease in purchasing power. However, Studies conducted by Tür *et al*. (2016) shows a continuous increase in passengers and commercial vehicles registered in Tanzania from 2007 to 20016 which disagrees with the pattern observed above. So far there is limited studies on Tanzania importation rate of mobile machinery. Studies on importation rate of mobile machinery in other countries are available but they are not suitable for comparison since importation rate of country to country differs depending on the economic status



	2012	2013	2014	2015	2016
Agriculture tractor	1,868	1,390	2,152	1,431	1,402
Construction equipment	798	753	1,063	653	654
Heavy load Vehicles	6,055	7,041	10,124	5,815	3,829
Heavy Passenger Vehicle	2,033	3,479	6,377	3,705	3,197
Light Load Vehicle	4,913	7,125	10,858	6,640	5,823
Other	441	362	1,378	1,719	949

Year

Figure 3(a): Imported mobile machinery for the year 2012 – 2016: Mobile machinery with less 11,000 units per year.

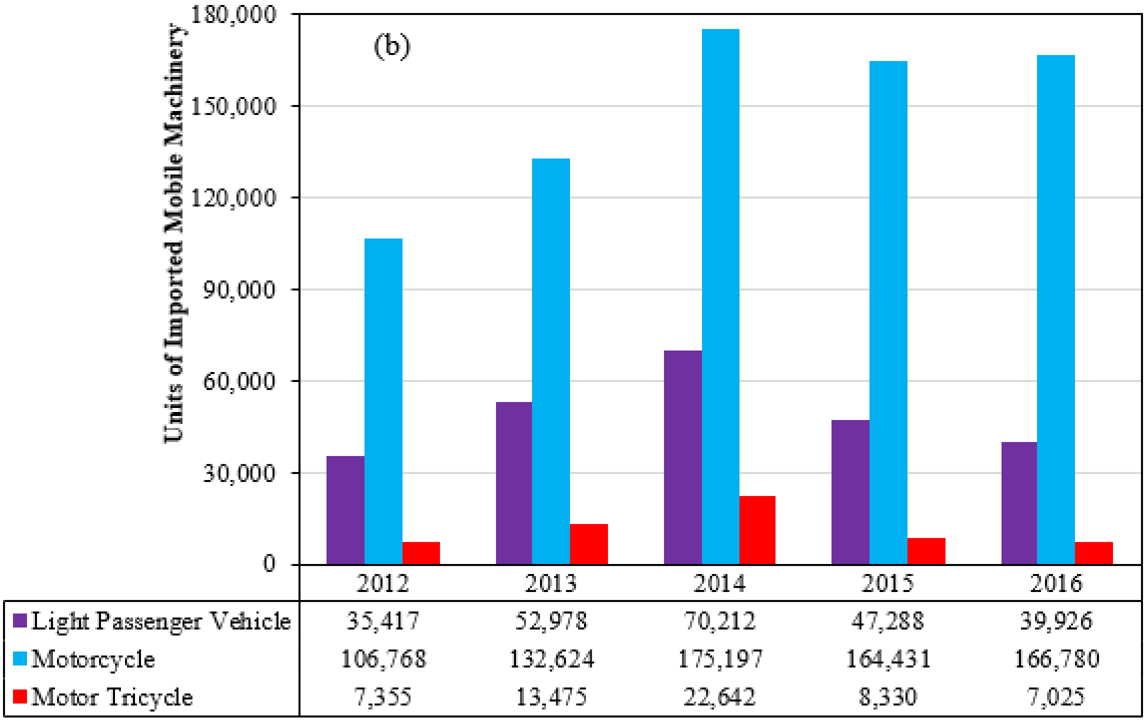


Figure 3(b): Imported mobile machinery for the year 2012 – 2016: Mobile machinery with greater than 11,000 units per year.

Table 2 indicates the total number of imported vehicles and machineries from January 2002 up to November 2017. The total number of registered vehicles and machineries from Jan 2002 to Nov 2017 was about 2,304,408 with a total of 2,536,684 batteries. Based on Tür *et al*., (2016) method; it is expected that about 2 million batteries are potential for recycling.

Table 1: Total number of registered vehicles and machinery from Jan 2002 to Nov 2017

Category	No. of Vehicles	No. of Batteries per vehicle	Total Batteries
Agricultural Tractor	21,672	1	21,672
Agricultural Trailer	972	0	0
Construction Equipment	9,088	2	18,176
Heavy Load Vehicle (GVM > 3500Kg)	102,365	2	204,730
Heavy Passenger Vehicle (12 or more persons)	60,370	2	120,740
Light Load Vehicle (GVM 3500kg or Less)	101,597	2	203,194
Light Passenger Vehicle (Less than 12 persons)	574,736	1	574,736
Motor Tricycle	77,856	1	77,856
Motorcycle (less than 3 wheels)	1,308,844	1	1,308,844
Others	6,736	1	6,736
Trailer	40,172	0	0
Total:	**2,304,408**		**2,536,684**

Spent Acid Battery Collection

In Tanzania, the collection network of used lead acid batteries (ULABs) starts by small-scale scrap ULAB dealers who receive and/or search for scrap batteries from all regions in Tanzania and are located mainly in the big cities. In this study several small-scale dealers were consulted at Temeke, Keko, Buguruni, Tabata-Reli, Mwenge and Tegeta in Dar es Salaam. In Mwanza region, small scale dealers were located at Mwananchi - Buzuruga, proximity to Kishimba factory and at Kilimahewa. Some of the small-scale dealers' agents whom were reported to engage in this business could not be located. Small scale scrap dealers collect the ULABs in small quantities from motor vehicle owners, accumulate them and later sell them to local agent dealers.

The researchers collected data from dealers/collectors as presented in Table 3. The results show that the local price offered by the dealers to individual sellers of ULABs was between TZS 600/kg to TZS 1,350/kg while the dealers sold the batteries to the recyclers. The selling price to the recyclers ranges between TZS 950/kg to TZS1600/kg depending on weight and size. The collection capacity ranges between 0.06 to 40 tons per month, while the whole quantity collected is always sold at the end of the month.

Customers of the collected ULAB were identified; others were recyclers and others were still in the feasibility stage of recycling. GAIA, Steelcom, OK Plast Ltd, Kamdhenu, "Kwa Mpalestina" and "Kwa Mzungu" located in Dar es Salaam and NADAKA Industrial Products ltd (NIDL) located in Mwanza are some of the examples of ULABs recyclers in Tanzania. Others include small scale dealers and local agents.

It was also reported that there were uncontrolled collection and export of ULAB through Zanzibar. This has created insufficient supply of ULABs to the recyclers in Tanzania mainland. The export practice is carried out by small groups of individuals whose data were not available and difficult to quantify during the survey. The researchers were informed by the local battery scraper dealers about the existence of some mobile buyers that collect used batteries from small dealers and export them through Zanzibar. Furthermore, it was reported that the dealers/collectors in Mwanza export the ULAB to Kenya. It was further reported that exporters are offering relatively high price. The ULAB export is illegal and against national Regulations and the Basel International Convention.

Table 2: Used Lead Acid Battery data collected from local dealers

Description	Scrap collector				
	1	2	3	4	5
Location	Mwenge	Mwenge	Temeke	Temeke	Temeke
Commencement of collection	2007	2017	2010	2017	2010
Collection per month (tons/month)	24-40	2	6 - 7	0.06-0.1	4
Quantity sold per month (tons/month)	24-40	2	6 - 7	0.06-0.1	4
Buying Price (TZS/kg)	1,100-1,350	600	1,000 - 1,200	600	1,000
Selling Price (TZS/kg)	1,400-1,600	950	1,300-1,400	800	1,300

Spent Acid Battery Recycling

Some of the identified companies provided data for the survey and others did not provide information. The recyclers that provided data for the study is Gaia Eco Solution which started recycling business in 2005. The provided data covers the year 2013 – 2017 of recycling the ULABs and are presented in Figure 5. Results show that the tonnage of batteries to be recycled declined with at a declining rate of about 2.2% per year which is against the annual estimate of amount of batteries available. However, the company has a capacity of 700 tons/month. The decline in recycling rate could be linked with ULAB exportation mentioned by dealers/collectors above since most of the discarded ULAB are collected by scrap collectors.

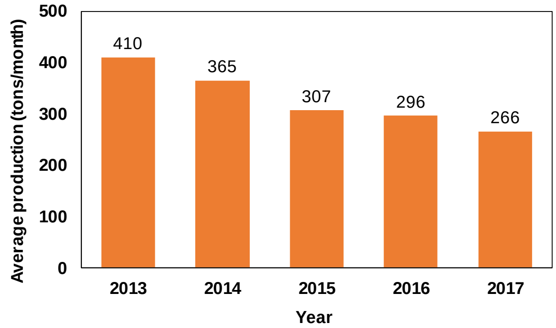


Figure 5: GAIA average recycling/ production per month.

The components of the recycling of ULABs in Tanzania such as the lead paste/ grids are exported by some of the recyclers operating within Tanzania. The major products from GAIA are pure lead metal at 99.98% and Antimony Lead Alloys. These are sold to the battery manufacturers and electrical cable manufacturers. GAIA exports lead ingots to Spain, Dubai, Saudi Arabia, India and Italy. OK Plast sells lead ingot to GAIA. It used to export lead ingots to Kenya, India and China.

On the other hand, NADAKA battery recycling plant in Mwanza region is scheduled to commence production of new lead acid batteries. The plant had established a pilot plant to evaluate the feasibility of recycling the spent battery products with the purpose of manufacturing automotive batteries. It has an envisaged capacity of treating 0.5 million battery units/year. However, a number of challenges were identified: (1) lack of local people with relevant skills of recycling batteries within the area; (2) inadequate support from the government; and (3) lack of banks that were willing to provide loan for the investment.

Regarding collection procedure, it was reported that the easiest way of ULABs collection is through a local agent because collection storage and transportation is expensive. The general movement of ULABs and LABs in Tanzania can be summarized in **Error! Reference source not found.**4.

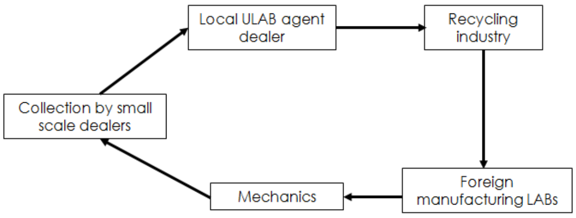


Figure 4: General movement of ULABs and LABs in Tanzania.

Challenges and Opportunities

The research identified some Challenges facing lead acid batteries recycling and opportunities that can be considered by the available recyclers and the new entry to manufacturing of new batteries in Tanzania.

Challenges

(a) Difficult in securing loans from the banks to start the investment of installing recycling smelter plant. The current economic situation makes things complicated in securing loans, liquidity is an issue, and the general confidence of the economy is an issue;
(b) The illegal export creates insufficiency of raw materials from the available recyclers within the country hence lowering the production of the local industries.
(c) Lack of skilled local people for recycling batteries; and
(d) Lack of statistics of spent lead acid batteries for domestic uses.

Opportunities

(a) In the National Five-Year Development Plan (FYDP), industrialization and economic growth have been emphasised (URT, 2016). This becomes an opportunity to the existing and new investors willing to invest in manufacturing of new batteries in Tanzania.

(b) Motive industrial battery market projection worldwide appears to increase (Jung *et al*., 2016). Continuous growth of the use of cars and the demand of cars in Tanzania assures the future market of the batteries. With the ever-increasing number of imported motor vehicles and motor cycles in Tanzania the demand for new batteries will also increase and the quantity of spent batteries will abundantly be available. This translates into new opportunities in battery servicing and manufacturing using modern technologies

CONCLUSION AND RECOMMENDATIONS

Recycling of Used Lead Acid Batteries in Tanzania has been always practiced formally and informally to generate lead ingots that are exported overseas for new batteries manufacturing. Based on the inventory of vehicles and plant equipment, 8,440 tonnes of ULAB are potentially available for recycling per annum. However, the two operational ULAB recycling plants process about 6,000 tonnes per year; this implies that about 29% of the collected ULAB do not reach the local lead smelters. Furthermore, the installed capacity utilisation of the local lead smelters is about 71%. This is due to insufficient supply of ULAB from collectors. However, based on dealers/collectors reports that some of ULAB are exported. This is illegal; it is against National Laws and International Convention that ban export of ULAB. Despite a number of observed challenges, the local ULAB recycling industry in Tanzania should explore opportunities of manufacturing new batteries since all batteries used in the country are imported. Therefore, the study recommends the following:

(a) The government should consider offering incentives for investment to add values to the produced lead ingots e.g., by producing certain class of batteries locally.
(b) The export ban of used Lead Acid Batteries should be fully enforced;
(c) The Government through its Vocation Centres should provide training on battery recycling to develop skills (capacity building); and
(d) More studies on used Lead Acid Batteries recycling in Tanzania should be conducted.

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