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Research Article

Perceived Economic and Environmental Benefits of Waste Battery Recycling in Lagos State, Nigeria

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ABSTRACT

The study assessed the economic and environmental benefits of waste battery recycling in Lagos State, Nigeria. Multistage sampling technique was employed to administer 65 copies of structured questionnaire to companies and individuals involved in waste battery recycling site area. Data obtained were analyzed using principal components analysis (PCA). The results obtained using component loadings of $\pm \geq 0.8$ as the criteria for selection of the variables reduction in importation (0.801) PC_1 was accountable for 20.35% of total variance, promotion of economic development opportunities (0.841) PC_2 was responsible for 19.02% of the total variance, job creation opportunities (0.871) PC_3 was accountable for 16.96% and reduction in industrial costs of sourcing material/energy production (0.911) PC4 was accountable for 15.35% of total variance as perceived economic benefits of waste battery recycling and they jointly accounted for 71.7% variation in the perceived economic benefits data set. The results obtained using component loadings of $\pm \geq 0.7$ as the criteria for selection of the variables also identified reduction of greenhouse emission (0.787) PC_1 was accountable for 24.67% of the total variance, soil erosion control (0.845) PC_2 was responsible for 19.89% of the total variance and energy/cost saving (0.789) PC_3 was accountable for 17.41% of total variance as perceived environmental benefits of waste battery recycling with 62% of the total variance in the environmental benefits data set. The study recommended the need for government to encourage waste battery collection by creating ready markets for scavengers of waste batteries.

Keywords: Economic; Scavengers; Waste batteries; Management; Health

INTRODUCTION

Batteries are integral to the functioning of our economy and support many aspects of modern lifestyles. They provide the portable power solution for mobile telecommunications, computers, construction tools, emerging electric vehicles and standby back up power in addition to many other solutions. However, we do not understand the magnitude of battery use from a mass flow perspective [1]. Batteries are indispensable thing in people's life because they are used in everything from clocks and watches, remote controllers, toys to cars among others. Batteries are one of many products that should never reach the landfill. Even the most seemingly harmless household battery contains hazardous chemicals which if allowed to enter the environment, can threaten both animal and human health, and the physical environment [2]. As a result of the diverse usefulness, the use of batteries has been in the increase over the decades.

The increasing use of portable electronic devices results in the increasing disposal of portable batteries that consist of various toxic substances. Lithium-ion batteries are the most commonly used batteries in portable electronic devices [3]. However, as a result of the increasing demands for batteries, the need to recycle used batteries has been on the increase. According to Bernardes et al., (2004), battery recycling is a recycling activity that aims to reduce the number of batteries being disposed as municipal solid waste. Batteries contain a number of heavy metals and toxic chemicals and disposing of them by the same process as regular household waste has raised concerns over soil contamination and water pollution [4]. The recycling of waste batteries reduces energy consumption, reduces greenhouse gas emissions, and results in considerable natural resource savings when compared to landfill [5]. The main benefit of not sending batteries to the bin is that the chemicals they contain will not enter the environment. Another is that well over 55% of a battery can be reused, as its steel, zinc, brass and other materials can be extracted at the recycling facility.

Recycling batteries also avoids a host of potential environmental

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problems and hazards, including the pollution of waterways, the leaching of heavy metals from landfills, and exposing the environment to strong acids and lead. The acids in batteries can burn skin and cause significant damage to eye tissue [6]. The awareness of waste battery recycling has taken the center stage across the globe due to the economic and environmental benefits associated with recycling. For instance, Hu in 2015 examined the opinions of 160 residents, college students and middle school students. Among them, 33.7% will put waste batteries at home; 13.4% will collect waste batteries and put them in recycling bins, while 27.1% will throw them away together with domestic waste. In China, 10,000 tons of waste batteries are produced each year [7]. The study stated that the total amount of waste batteries is high and it inevitably pollutes the environment. Among them, cadmium, mercury, zinc, lead and chromium are hazardous wastes.

Battery specialists and environmentalists give a long list of reasons to recycle batteries. The materials recovered could be used to make new batteries, lowering manufacturing costs. Currently, those materials account for more than half of a battery's cost. In addition to potential economic benefits, recycling could reduce the quantity of material going into landfills. Cobalt, nickel, manganese, and other metals found in batteries can readily leak from the casing of buried batteries and contaminate soil and groundwater, threatening ecosystems and human health [8]. Batteries can have negative environmental effects not just at the end of their lives but also long before they are manufactured. Based on this, Argonne Gaines cited by Jacoby in 2019 pointed out that more recycling means less mining of virgin material and less of the associated environmental harm. For example, mining for some battery metals requires processing metal-sulfide ore, which is energy intensive and emits sulphur dioxide that can lead to acid rain.

Economic view of recycling

The discharge in Figure 1, the production process is divided into two parts, recoverable materials and waste. In turn, the recoverable materials are divided into two parts, those which can be recovered economically and those which cannot and are added to waste.

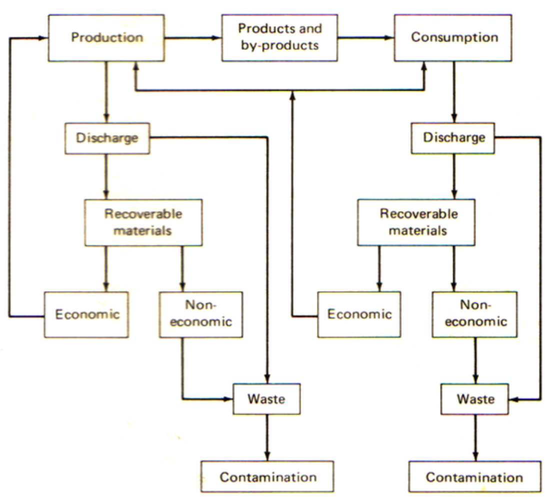

Figure 1: The economics of waste and recycling.

Technological development could reduce the amount of materials which are currently not economically recoverable. In other words, technological change could shift materials from the non-economic waste category to the economic category of recoverable materials [9].

There is always waste from the production process. Again, with technological change the amount of waste can be reduced through the creation of new products from final or intermediate wastes.

A firm's investment on research and development decisions may be directed to a better use of existing resources; or, the research and investment may be directed to totally new and different products, new plants, and mergers. Expected return is an important element in a firm's decision-making process. Society's saving from recovery may be greater than the cost of recovery, but if a firm's saving is not greater than the cost of recovery, the firm will have no incentive to undertake investment in recovery equipment (Figure 1).

METHODOLOGY

The consumption side of Figure 1 raises additional points. Again, the discharge can be separated into recoverable materials and waste. The recycling of recoverable materials may be economic or non-economic the latter being added to waste. Recycled materials may be returned to the production or consumption process. Waste batteries are recovered and re-enter into the production process. Other materials, such as used steel, zinc, brass and other materials enter the consumption process. Cost per unit of recovered materials compares favorably to new product and resource prices makes recycling feasible. Sometimes materials are recycled because a firm does not incur the cost of collection.

As the population grows, air, water, and land are becoming more contaminated. In order to protect these valuable resources, recycling may be required for all processes. The home or city should discharge only water; the smokestacks should discharge only air, and so on. Research and technological development must be directed toward, if not the elimination of impure discharges, the minimization of them by maximal use of recycling. Elements of the problem become world-wide and the industrialized nations bear the responsibility of taking the initiative to effect change [10].

It should be noted that recycling is a part of natural processes. The earth's water cycle is a closed system. Carbon dioxide is converted to oxygen by plant life. Perhaps the process of production and consumption must also become a closed system. The frontiers of the world are vanishing and the density problem is real. In the absence of population control, the only other vaguely possible solution is to create a new frontier by exporting people to outer space. In the animal kingdom, there is a geographical dispersion of the population. Each animal (or group) stakes out a territory which under existing conditions is sufficient to sustain life. Man is the exception he congregates by creating cities and the density problem increases.

The discussion to this point has focused upon those elements which cause and contribute to the environmental problem. At the center of the problem is the fact that all costs resulting from the production of goods are not included in the prices of those goods. Some costs, such as those of effluent disposal, are shifted to society as losses of clean air and water. Correction of the environmental problem will involve enormous costs. The initial impact of the costs of environmental improvement will fall upon the polluters [11].

In spite of environmental challenge, waste battery is an inevitable consequence of the need for survival. In order to live, we need batteries to make living worthwhile. In the process of trying to satisfy human needs, we create waste batteries. In Nigeria and

Lagos State in particular, waste management is a major concern. Hence, the major problem of waste battery generation in Lagos State is waste battery management, as the waste management systems put in place by the government has not been effective in ensuring appropriate waste management in the state. Studies have been carried out on waste battery recycling. A good number of the available studies principally looked at the recycling of waste battery from a descriptive perspective [12]. Others looked at the environmental and economic impacts of waste battery recycling [13]. These studies among others did not use empirical data to assess the economic and environmental benefits of waste battery. It is on this research gap that the present study is carried out. The present study examines the perceived economic and environmental benefits of waste battery recycling in Lagos State. The good news however is that several recycling companies now operate in Lagos State and many of the companies are owned by private individuals. These recycling companies help in waste battery management with inherent economic and environmental gains.

Study area

The study area is Ikorodu Local Government Area of Lagos State, Nigeria. Ikorodu is bounded to the south by the Lagos Lagoon, to the north by a boundary with Ogun State, and to the east by Agbowa-Ikosi, a town in Epe Division of Lagos State. The area has grown significantly in the past 40 years and is divided into sixteen or seventeen "Ituns" or minor areas. The main industries in the town are trading, farming and manufacturing. Ikorodu has a large industrial area containing several factories including aluminum recycling firms. The town of Ikorodu itself is home to branches of several established Nigerian banks. Ikorodu is the fastest growing town of Lagos metropolis, owing in part to increasing influx of people from Ikorodu's surrounding towns and villages attracted by the town's proximity to Lagos.

Data types and sources

This study basically relied on primary data types. The primary data required for the study included data on the economic benefits of waste battery recycling and data on the environmental benefits of waste battery recycling. In addition, data on the environmental and economic benefits of waste battery recycling were gathered through the administration of structured questionnaire to companies and individuals involved in waste battery recycling.

Method of data collection

This study basically employed a multi-stage sampling technique consisting of three stages. In the first stage, stratified sampling technique was employed to administer copies of questionnaire to staff of selected recycling companies and private individuals involved in waste battery collection. In the second stage, random sampling technique was employed to select three (3) waste battery recycling companies in Lagos State. In the third stage, the purposive sampling technique was employed to administer 65 copies of structured questionnaire to staff of the selected companies as well as individuals engaged in waste battery collection and sales as a source of livelihood. In all, 35 copies were administered to individuals engaged in waste battery collection and sales, while the remaining number was administered to staff of the selected companies. Due to the challenges encountered in approaching staff of the companies, possible attempts were done to administer copies to them.

Questionnaire administration

A structured questionnaire was administered to staff of selected waste battery recycling companies and individuals engaged in waste battery collection and sales. The questionnaire was administered by the researcher with the assistance of two research assistants. The questionnaire had sets of questions designed to give answers to quantify the perceived economic and environmental benefits of waste battery recycling. It was divided into three sections. Section A had questions that measure the socioeconomic characteristics of respondents; Section B had a set of questions that measure the economic benefits of waste battery recycling, while Section C had a set of questions that measured the environmental benefits of waste battery recycling. The items in Sections B and C were measured using 4-point ordinal scales with responses ranging from Strongly Agree=SA; Agree=A; Disagree=D to Strongly Disagree=SD.

Data analysis

Data obtained from the administered questionnaire were analyzed using Principal Components Analysis (PCA). The statistical analyses were performed with the aid of SPSS (Statistical Package for Social Sciences) version 21.0. Principal components analysis was used to identify significant economic and environmental components or dimensions of waste battery recycling. PCA is a very powerful multivariate statistical technique which is performed to reduce the dimensionality of a data set consisting of a large number of interrelated variables, while retaining as much as possible the variability present in data set. PCA attempts to transform a large set of inter-correlated indicators into a smaller set of composite indicators, uncorrelated (orthogonal) variables called Principal Components (PCs), and simplifies the structure of the statistical analysis system. PCA was performed in the present study to reduce the economic and environmental benefits data set as well as to extract a small number of latent factors for analyzing relationships among the elements [14]. This was achieved by extraction only components with eigenvalues >1 after Varimax rotation.

RESULTS AND DISCUSSION

Perceived economic benefits

Principal Components Analysis (PCA) was employed in this part of the analysis to identify principal components perceived by the respondents as the perceived economic benefits of waste battery recycling. This statistical technique was employed due to the number of variables used to measure the perceived economic benefits of waste battery recycling. The result obtained is shown in Table 1. PCA result of 8 variables resulted in the extraction of four components that accounted for 71.7% of the variation in the data set. Using component loadings of $\pm \geq 0.8$ as the criteria for selecting variables, Principal Component One (PC_1) had strong and positive loading on one variable; the only variable was waste battery recycling reduces importation (0.801). PC_1 was accountable for 20.35% of total variance in the perceived economic benefits of waste battery recycling and the positive loading of the variable indicated increase in waste battery recycling reduces importation. As a result of the variable that loaded on PC_1, it therefore represented reduction in importation. PC_2 also had only one variable that loaded positively on it; the only variable was waste battery recycling promotes economic development opportunities (0.841). PC_2 was responsible for 19.02% of the total variance in the variable set and represented promotion of economic development opportunities.

PC_3 was accountable for 16.96% of total variance in the perceived set of data and had one variable that loaded on it. The variable was Waste battery recycling creates job opportunities (0.871). The positive loading of the variable indicated increase in job opportunities with the increase in waste battery recycling. Based on the nature of variables that loaded in PC_3, it could be said to represent job opportunities. PC4 was accountable for 15.35% of total variance in the set of data and had only one variable that loaded on it. The variable was waste battery recycling saves industries the costs of sourcing material and energy production (0.911). PC4 symbolized reduction in industrial costs of sourcing material and energy production. From the result presented in Table 1, it is glaring that the significant dimension in perceived benefits of economic benefits of waste battery recycling are reduction in importation, promotion of economic development opportunities, job creation opportunities and reduction in industrial costs of sourcing material/energy production.

These four factors to a large extent explain to perceived benefits of economic benefits of waste battery recycling. The first extracted component means that waste battery recycling results in the reduction in importation. This is expected as recycling of waste battery will reduce the rate of battery importation and will rather encourage exportation and the increase in foreign exchange. This has immense impact on the economy by promoting economic growth. Reduction in importation will encourage the growth of local industries thereby making locally produced batteries viable in the market. The second extracted component identifies the promotion of economic development opportunities. The recycling of waste batteries creates avenue for local business to flourish. The availability of raw materials will attract local and foreign industries which will foster economic growth. Through this way, large quantities of batteries will be locally produced and sold to other countries.

The third extracted component points at job creation opportunities associated with waste battery recycling. Through recycling, many battery recycling plants will be set up which will result in a long chain of collection and delivery of waste and finished or recycled batteries. Waste battery recycling is an integrated process that begins with waste battery material collection from different locations. After collection, these batteries go through a thorough sorting process to separate various materials as well as different quality goods. All these process create jobs for different groups of people. From the collection of materials to selling, recycling businesses need varying degrees of skilled and semi-skilled employees to perform recycling industry jobs. This goes to show the benefits of waste battery recycling. Another benefit of waste battery recycling is energy saving. This is expected as the amount of energy needed to extracted raw materials to manufacture batteries is preserved and this saves the industry huge amount of energy and cost to producing new ones. In a related study, Belinda (2006) asserted that recycling saves precious natural resources, energy, time and money which will benefit the earth and also the economy and local communities.

The result in Table 1 therefore shows that reduction in importation, promotion of economic development opportunities, job creation opportunities and reduction in industrial costs of sourcing material/energy production as the main economic benefits of waste battery recycling. These findings are consistent with those of Beaudet et al., (2020) that battery recycling goes a long way in generating local economic activity. The study stated that recycling is expected to become a significant industry in the future generating billions of dollars in revenue, tax income, and jobs, many of which would be in countries and regions that currently do not benefit from battery-related industrial activities. That as a result of the high cost of transporting used battery packs, there are strong incentives for localizing at least part of the recycling infrastructure. The study of Beaudet et al., (2020) further stated that battery recycling reduces reliance on specific suppliers. It argued that apart from expanding the availability of materials for battery manufacturing, recycling also offers the possibility of bypassing foreign suppliers of raw and refined Lithium-Ion Batteries (LIB) materials (Table 1).

Table 1: PCA result showing perceived economic benefits.

Variables	Principal components			
	PC_1	PC_2	PC_3	PC_4
Reduces importation	0.801	-0.21	0.117	-0.351
Helps in the provision of household income	0.715	0.037	-0.203	0.261
Helps in maintaining local manufacturing firms	0.681	0.365	0.203	0.236
Promotes economic development opportunities	0.022	0.841	0.049	-0.265
Generates revenue to government *via* taxes	0.029	0.714	0.085	0.271
Creates job opportunities	0.001	-0.094	0.871	0.026
Satisfies the increasing demand for raw materials	0.027	0.342	0.695	0.086
Saves industries the costs of sourcing material/energy	0.102	-0.006	0.098	0.911
Eigenvalues	1.63	1.52	1.36	1.23
% variance	20.34	19.02	16.96	15.35
Cumulative exp.	20.34	39.37	56.33	71.68

Perceived environmental benefits

PCA was also employed to identify the perceived environmental benefits of waste battery recycling. The result obtained is shown in Table 2. PCA result of 7 variables resulted in the extraction of three components that accounted for 62% of the variation in the data set. Using component loadings of ± ≥ 0.7 as the criteria for selecting variables, Principal Component One (PC_1) had strong and positive loading on a variable which was reduces greenhouse emission (0.787). PC_1 was accountable for 24.67% of total variance in the data set. PC_1 symbolized reduction in greenhouse emission. PC_2 also had one which was reduces soil erosion (0.845). PC_2 was responsible for 19.87% of the total variance in the data set and represented soil erosion control. PC_3 was accountable for 17.41% of total variance in the data and had one variable which was recycling saves energy that is it saves the amount of energy needed to manufacture new products (0.789). PC_3 represented energy/cost saving. The result presented in Table 2 identifies reduction of greenhouse emission, soil erosion control and energy/cost saving as the perceived environmental benefits of waste battery recycling. These three factors explain to a large extent perceived benefits of environmental benefits of waste battery recycling. The first extracted component explains the importance of waste battery recycling on the reduction of greenhouse emission. Recycling stops incineration process and this helps to reduce the emission of greenhouse cases. The reduction in greenhouse gases ensures environmental sanity and sustainability. In line with this, Martins (2021) stated that lithium batteries can cause landfill fires that can smolder for many years. As a result, the toxic chemicals released into the air negatively affect our breathing and contribute to global warming. The vaporized form of improperly exposed batteries also gets trapped in the atmosphere and pollutes lakes and streams in the form of rain. Similarly, Lundstrom (2021) stated that the carbon footprint of the raw material obtained by the recycling process studied is 38% smaller than that of the virgin raw material. The difference is even greater if copper and aluminum recovered during mechanical pre-treatment are included. The results also point to problem areas. It should be noted that when depleted batteries are tossed into the trash, they end up in landfills where they decay and leak. As batteries corrode, their chemicals soak into soil and contaminate soil, groundwater and surface water. Our ecosystems, which contain thousands of aquatic plants and animals, are compromised when filled with battery chemicals. This means that when we drink from tap water faucets, we could be ingesting dangerous metals.

The second extracted component shows that importance of battery recycling on soil erosion control. This is expected as the excavation of the earth's surface for raw materials is put on hold. When exploitation is carried out, the land is usually tampered on which gives way to land degradation. Vegetation is cleared and the soil is left bared without any form of protection which exposes the soil/land to the forces of denudation. The absence of mines to extract raw materials results in the protection of the environment from damage. The use of mines for the extraction of raw materials used in the manufacturing of batteries can cause the destruction of soil and local habitats through deforestation, explosions and drilling. Once in operation, mines release large amounts of greenhouse gases into the atmosphere, and they can potentially contaminate the surrounding soil with heavy metals and toxic minerals. Thirdly, the extracted component highlights the benefits of waste battery recycling on energy/cost saving. The amount of energy usually required to get raw materials is saved; this also goes to the cost of sourcing for raw materials. The cost of hiring workers/labourers, buy new excavators, fuels and transportation is saved through recycling. This makes the manufacturing process easier and without much stress. In a similar study, Boyden et al., (2016) stated that recycling batteries is beneficial to the environment. That the recycling of lithium-ion batteries in particular reduces energy consumption, reduces greenhouse gas emissions, and results in 51.3% natural resource savings when compared to landfill. The study further stated that the majority of benefits occur as a result of avoiding virgin materials production (Table 2).

Table 2: PCA result showing perceived environmental benefits.

Variables	Principal components		
	PC_1	PC_2	PC_3
Reduces greenhouse emission	0.787	0.028	0.058
Results in the protection of habitats	0.65	-0.269	0.339
Reduces air, water and soil pollution	0.628	0.453	-0.228
Protects the environment from damage	0.614	0.156	0.051
Reduces soil erosion	0.142	0.845	-0.082
Saves energy	0.174	-0.146	0.789
Ensure resource conservation and sustainability	-0.108	0.594	0.645
Eigenvalues	1.73	1.39	1.22
% variance	24.67	19.87	17.41
Cumulative exp.	24.67	44.54	61.95

CONCLUSION

The study has shown that waste battery recycling positively impacts on the environment. The outcome of the study shows that the positive gains of waste battery recycling are far greater than the negative effects. The study clearly shows that reduction in importation, promotion of economic development opportunities, job creation opportunities and reduction in industrial costs of sourcing material/energy production are significant dimensions or perceived economic benefits of waste battery recycling. It further reveals that reduction of greenhouse emission, soil erosion control and energy/cost saving are perceived environmental benefits of waste battery recycling. The study shows that waste battery recycling does not significantly impacts on the environment. The study suggests that Government should also encourage waste battery collection by creating ready markets for scavengers of waste batteries. This will go a long way in reducing the quantities of batteries in the environment. And that waste batteries should be properly collected and taken for recycling on time and as at when due to reduce groundwater pollution as well as reduce bioaccumulation of metals in the soil water.

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