

Effect of Automobile Battery Wastes Disposal on Soil Health and Fertility Indices

ABSTRACT

This study was designed to assess the impact of automobile battery wastes disposal on the indices of soil health and fertility. Soil samples were collected from three major mechanic villages in Akure and Owo in Ondo State. The physicochemical parameters were analysed using standard methods while the heavy metal content was assessed using spectrophotometer. Also, the microbial population was determined using pour plate method and some biochemical tests. The results show that soil sample from Owo had the least total bacterial count of 65.10×10^5 CFU/g while sample from Akure 2 had the highest bacterial count of 185.50×10^5 CFU/g. The probable organisms isolated from the samples were *Klebsiella* spp, *Escherichia* spp, *Staphylococcus* spp, *Proteus* spp, *Pseudomonas* spp, *Bacillus* spp, *Serratia* spp and *Enterobacter* spp. There were significant differences between the physicochemical parameters of the contaminated soil samples and the uncontaminated control soil. The electrical conductivity of the contaminated soil samples (1.20, 0.92 and 0.38) were higher significantly ($p < 0.05$) than the uncontaminated (0.21) soil sample. The pH values were acidic (4.57) compared with the control (7.42). Other indices like C, Ca, CEC, bulk density among others have values that were different significantly ($P < 0.05$) between the contaminated soil and the control. In addition, the level of heavy metals such as Lead, Cadmium and Chromium in the contaminated soil were significantly higher than the control soil sample. The study confirms that the health indicators of the battery waste receiving soil in the studied area are highly compromised therefore it may need remediation to reduce soil pollution.

Keywords: Automobile, Battery, Wastes Disposal, Soil Health, Bacteria

Introduction

In the developing countries around the world, the issues pertaining to environmental pollution is becoming a big challenge. Although, there are myriads of legislature against this menace in most of these countries, most lack strict enforcement to control human activities which contribute to this pollution which invariably leads to diverse risks to the community. As urbanization and industrialization are pursued vigorously by these countries, high number of pollutants are discharged unabatedly into the environment (Begum *et al.*, 2009).

Attention is usually focused on water and air pollution due to the fact that they are directly linked with human health and their effects are felt more quickly than other spheres of environmental pollution such as soil. The most obvious soil polluting activities are centered around solid waste disposal. However, these days wastes from automobiles are generating a lot of concerns in the environmental science world since they usually contain recalcitrant substances like heavy metals and polycyclic aromatic hydrocarbons that are known to persist in the environment for a long time (Fan *et al.*, 2020).

Many times, mechanic workshops in Nigeria are situated in residential zones. The new policy of the government to pull the automechanics, technicians and other forms of autorepair workers together in an automobile mechanic village is creating another environmental disaster (Duru *et al.*, 2019). The reason for this is evidently to reduce the proliferation of these workshops in the environment in a bid to curb environmental pollution. However, the aim is being defeated as these centers discharge a lot of toxic wastes into the soil on daily basis all over the country.

The increase in the level of electronic wastes as a result of battery waste disposal may become a big problem in the nearest future as the automobile industry is gradually transiting to electromotive vehicles which are run on rechargeable batteries. The sale of these vehicles is estimated to be above thirty million unit come year 2030 (Mayyas *et al.*, 2019). The low economic value of recycling battery wastes on one hand and lack of proper regulation for the management of the electronic wastes are the major contributing factors in the indiscriminate disposal of the battery wastes in to the soil. The components of these wastes eventually will find their way into the water ecosystem where they are likely to cause serious damages to the biotic and abiotic components of the habitat (Shaikh *et al.*, 2020).

Batteries which are the main source of power for many devices and they are contributing significantly to the overall e-wastes generated around the world. Components of these batteries are majorly made up of large amount of heavy metals such as Mn, Cd, Pb and Li as well as other contaminants which are highly toxic to the ecosystem (Guo *et al.*, 2018, Dutta *et al.*, 2018). These heavy metals have been reported to cause impairments to various organ-systems in human body and disrupt reproduction, immunity as well as kidney functions as in the case of lead (Silva *et al.* 2016), and loosening of bone, damage of kidney and tumor development as in the case of cadmium (Itoh *et al.* 2014).

Many of the new components of batteries especially those being included in the electric vehicles production like ionic liquids, graphenes and oxides of metals are reported to be high impact

indicators of ecotoxicity (Nwachukwu *et al.*, 2010, Yang *et al.*, 2020). Nonetheless, there is dearth of information on the effect of these materials on soil ecosystem as well as their effect on groundwater. Moreover, the storage devices for the emerging energy sources may be more problematic to handle compared to the more known conventional ones (Liu and Ren, 2020, Xia *et al.*, 2013). Therefore, this study was designed to investigate the effect of battery waste disposal on the physicochemical and microbiological parameters of the receiving soil both of which are indices of soil health and its fertility.

MATERIALS AND METHOD

Sample Collection: Soil samples were collected randomly from disposal point of battery chargers wastes at mechanic villages in Owo and Akure cities of Ondo state, Nigeria from 0 – 15cm depth into sterile wide-mouthed screw cap bottles because oil penetration to the soil is very slow and hardly exceeded 13.5cm.

Physicochemical Analysis: properties like the pH, temperature, water retention capacity, transparency, colour, total dissolved solid (TDS), hardness, organic matter, C, N, P and moisture were determined using the method described by UNEP (2003) and CEC (2016).

Determination of minerals and heavy metals

The minerals and heavy metals present in the samples were assayed using the Atomic Absorbance Spectrophotometer (AAS) method.

Microbial Analysis

Samples of the pond water were serially diluted in ten folds. Total viable heterotrophic aerobic plate counts were determined by plating in duplicate, using pour plate technique. Molten nutrient agar, Salmonella- Shigella agar, Manitol salt agar, MacConkey agar and Eosin Methylene Blue agar at 45 °C were poured into the Petri dishes containing 1mL of the appropriate dilution for the isolation of the total heterotrophic bacteria, Salmonella and Shigella, Staphylococci group, coliforms and *Escherichia coli* respectively. They were swirled to mix and colony counts were taken after incubating the plates at 35 °C for 24 hours (Akinnibosun *et al.*, 2020)

RESULTS AND DISCUSSION

The total heterotrophic bacterial count (THBC) and heavy metal resistant bacteria (HMRB) are presented in Table 1. Battery waste polluted soil sample from Owo had the least THBC (65.10×10^5 CFU/g) which indicated that it is less contaminated amongst the tested samples. Sample from Akure 2 had the highest THBC value (185.50×10^5 CFU/g) followed by sample from Akure 1 (154.33×10^5 CFU/g). Also, the HMRB ranged from 190.00 to 220.50×10^5 CFU/g with Owo sample having the least and Akure 2 with the highest value against the control (94.33×10^5 CFU/g). This is an indication that the microfloras of the tested soils are forming resistance to the heavy metals present which in turn will help in biosorption.

Table 1: Total heterotrophic bacterial count on battery waste polluted soil ($\times 10^5$ cfu/g)

Sample	THBC	HMRB
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Control	130.00±2.50 ^b	94.33±1.60 ^a
Akure 1	154.33±5.15 ^c	211.50±10.20 ^c
Akure 2	185.50±3.88 ^d	220.50±14.05 ^c
Owo	65.10±1.25 ^a	190.00±8.71 ^b

THBC = Total heterophilic bacterial count, HMRB = Heavy metal resistant bacteria, values are Mean±SEM, those followed by different alphabeth along columns are significantly different at P<0.05

Higher THB counts in battery waste contaminated soils may be linked with the presence and availability of high density of nitrogen and phosphorus in the soil which may have served as stimulus for the growth of bacterial community in the soil. Also, the availability of the major and minor elements as revealed in the physicochemical properties is a major factor encouraging the growth and perpetuation of the isolated microbial species in the contaminated soil (Lee *et al.*, 2003).

Table 2 presented the morphological and biochemical characterization of the isolates from the tested soil samples. The probable organisms were revealed to be *Klebsiella* spp, *Escherichia* spp, *Staphylococcus* spp, *Proteus* spp, *Pseudomonas* spp, *Bacillus* spp, *Serratia* spp and *Enterobacter* spp. Higher counts of THB might as well be due to the abilities of the organic wastes to neutralize the toxic effect of the battery electrolyte residue on the microbial population by rapidly improving the physicochemical characteristics of the soil (Floch, 2011). The organic wastes might have helped in improving the soil aeration, thus providing adequate oxygen required by the microbial community which as a result favored the growth of indigenous bacteria in the soil.

Table 2: Preliminary identification of the isolates

Isolate code	Plate morphology	Gram reaction	Shape	Cat	Lac	Suc	Fru	Mal	Glu	Man	VP	GH	Probable organism
CI1	Large, circular, opaque, fruity smell	-	Rod	+	+	-	+	+	+	+	-	+	Klebsiella spp
CI2	Circular, opaque, smooth, glistening	-	Rod	+	+	+	+	+	+	+	-	+	Escherichia spp
CI3	Round, entire edge, convex, yellowish	+	Cocci	+	-	+	+	+	+	+	-	+	Staphylococcus spp
CI4	Whitish, round, entire, convex surface	-	Rod	+	+	-	+	+	+	+	-	+	Proteus spp
CI5	Dotted surface, whitish, opaque	-	Rod	+	-	+	+	+	+	+	-	+	Pseudomonas spp
NI1	Opaque, circular, depressed	-	Rod	+	+	-	+	+	+	+	-	+	Klebsiella spp
NI2	Whitish, spherical, raised	+	Rod	+	+	+	+	+	+	+	+	-	Bacillus spp
NI4	Round, rough surface, smooth	-	Rod	+	+	+	+	+	+	+	-	+	Serratia spp
NI5	Yellowish, round, raised	+	Cocci	+	-	-	+	+	+	+	-	+	Staphylococcus spp
NI6	Rough edges, whitish, flat, smooth	-	Rod	+	-	+	+	+	+	+	-	+	Proteus spp
NI7	Round, whitish, raised	-	Rod	+	-	-	+	+	+	+	-	+	Enterobacter spp
NI8	Rough surface, opaque, Rhizoidal edges	+	Rod	+	+	-	+	+	+	+	+	-	Bacillus spp

Key: - =negative, += positive

Table3: Physicochemical parameters of battery waste polluted soil

Parameter	C	Akure1	Akure2	Owo
Moisture content (%)	11.19±0.01 ^d	10.02±0.05 ^c	9.11±0.08 ^b	7.97±0.50 ^a
pH	7.42±0.05 ^c	5.17±0.01 ^b	5.31±0.00 ^b	4.57±0.01 ^a
Organic matter(%)	2.39±0.01 ^a	3.14±0.02 ^b	2.18±0.02 ^a	8.31±0.04 ^c
Phosphorus (g/kg)	5.22±0.20 ^c	4.13±0.01 ^b	4.20±0.04 ^b	3.22±0.02 ^a
%Carbon	4.67±0.15 ^a	5.31±0.00 ^b	5.17±0.01 ^b	6.22±0.01 ^c
%Nitrogen	0.31±0.02 ^b	0.32±0.03 ^b	0.32±0.03 ^b	0.21±0.00 ^a
Calcium (ppm)	11.00±0.25 ^a	44.2±0.02 ^c	46.8±0.01 ^c	37.2±0.15 ^b
Magnesium (ppm)	1.9±0.05 ^a	4.90±0.01 ^c	3.60±0.00 ^b	11.2±0.05 ^d
Potassium (ppm)	1.4±0.08 ^a	3.70±0.00 ^b	3.11±0.02 ^b	4.5±0.00 ^c
Conductivity (mS/cm)	0.21±0.00 ^a	1.20±0.01 ^{cd}	0.92±0.02 ^c	0.38±0.01 ^b
Bulk density	1.22±0.08 ^{cd}	1.09±0.01 ^a	1.16±0.03 ^b	1.54±0.00 ^d
Cation Exchange Capacity (CEC) (ppm)	301.2±15.02 ^d	272.4±10.04 ^c	268.2±0.03 ^b	241.5±10.00 ^a
Sand %	48.61±0.28 ^a	65.18±1.58 ^b	62.49±1.28 ^b	69.07±3.10 ^b
Clay%	26.72±3.05 ^d	8.25±0.58 ^c	7.79±0.03 ^b	6.04±0.06 ^a
Silt%	24.67±1.08 ^a	26.57±0.04 ^b	29.72±0.02 ^c	24.89±1.02 ^a

The physicochemical parameters such as Moisture content (%), pH, Organic matter (%), Phosphorus (g/kg), % Carbon, % Nitrogen, Calcium (ppm), Magnesium (ppm), Potassium (ppm), Conductivity (mS/cm), Bulk density, Cation Exchange Capacity (CEC) (ppm), Sand %, Clay % and Silt % of battery waste polluted soil were presented in Table 3. The electrical conductivity was higher significantly ($P<0.01$) in battery-contaminated soil samples (1.20 ± 0.01 , 0.92 ± 0.02 and 0.38 ± 0.01 for Akure 1, Akure 2 and Owo respectively) than uncontaminated (0.21 ± 0.00) soil sample which is a pointer to high level of ionic liquid contamination of the soil samples. Earlier, Hartsock *et al.* (2000) noted that electrical conductivity is usually proportional to the concentration of the dissolved substances in water or soil. The observed higher EC in the studied soil samples may have been triggered by the dissolution of various salts and freeing up of their cations in the soil.

The pH values obtained from the soil samples are quite acidic in nature and lesser than WHO permissible limit of 6.5-8.5, especially that of Owo (4.57 ± 0.01) against the control (7.42 ± 0.05) which is neutral. Since the survival of most microbial species is dependent on a certain pH range, soil pH is essential. Moreover, availability of nutrients can be affected by soil pH. This result agrees with the work of Orjiakor and Atuanya (2015). Earlier researchers like Pam *et al.* (2013) and Ajai *et al.* (2016) have made comparable submissions. The pH level determines the number and type of organisms inhabiting any habitat particularly the soil. These organisms also function in a dynamic way to affect the growth and development of the microbial communities in the soil as well as having impact on plant and animal health. Furthermore, pH determines the availability for uptake and the leaching of heavy metal content in the soil. In addition, Buxton *et al.* (2019)

submitted that metal cation solubility is inversely proportional to pH which means that the lower the pH the greater the metal solubility.

Other physicochemical factors such as carbon, calcium, CEC, bulk density, etc have significant difference ($P>0.05$) between the soil and control samples. Furthermore, the results for particle size distribution of the soil in the sampling sites range from 62.49 ± 1.28 - 69.07 ± 3.10 , 6.04 ± 0.06 - 8.25 ± 0.58 and 24.89 ± 1.02 - 29.72 ± 0.02 for sand, clay and silt respectively. This shows that the sand fraction was prominent than the clay and silt in all the sampling sites. This is supported by the report from Nwakife *et al.* (2022) where they obtained similar result for soil profile in polluted sites.

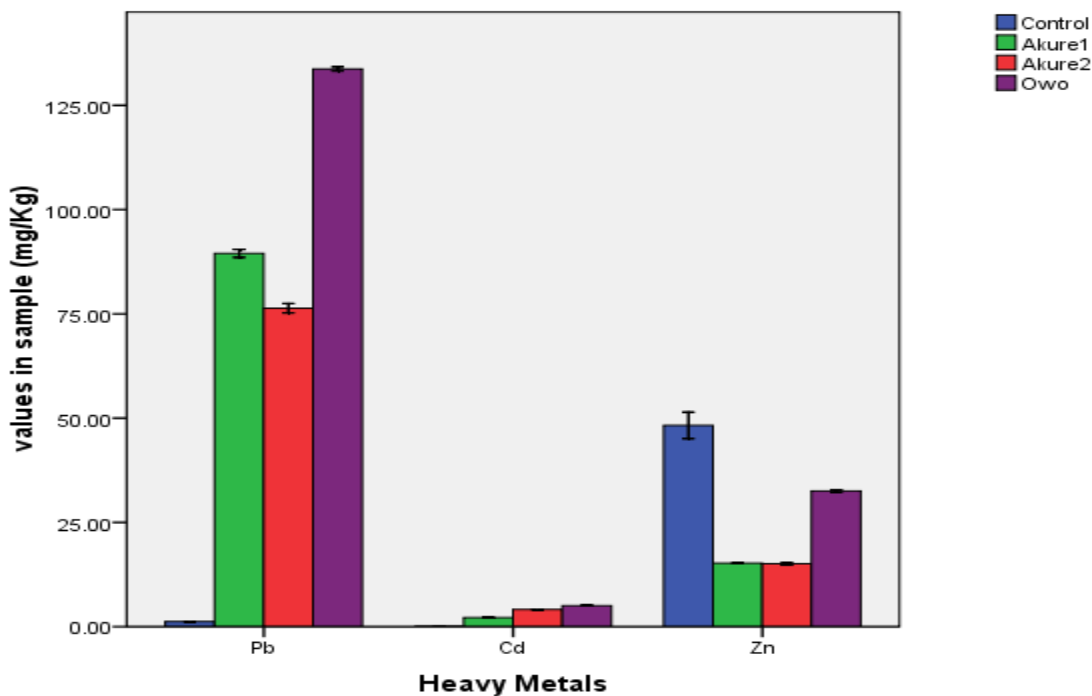


Figure 1: Selected heavy metal content of battery waste polluted soil

Carbon concentration was higher in the contaminated soil samples compared with the control soil sample while the nitrogen content not significantly different across the samples analyzed. This may be connected to other wastes that are deposited in the waste heaps as observed during sample collection. The lower content of phosphorus in the contaminated soil could be linked to the loosening of the soil particles thereby allowing leach out of the topsoil; a situation that can be accentuated by water during raining season as well as the presence of microbial hydrolytic polyphosphates according to Barel and Barsdate (2014).

Figure 1 presented the selected heavy metal content of battery waste polluted soil samples. The values of lead in the various sites were extremely higher than that of the control and the permissible limit (0.01 mg/kg) of WHO and shows that the concentrations of Cd in the study areas were low. This is an indication of heavy contamination which may be linked with the electrolytes used in most automobile which are usually lead based electrolyte. This was similar to the work of Nwakife *et al.* (2022) who also reported similar result.

The level of zinc in the contaminated soil samples as well as the control site were higher than WHO permissible limit (5 mg/kg). Interestingly, the level of zinc was higher in the control than the contaminated site. The reaction of zinc with other chemical species in the battery wastes may have caused the reduction of zinc in the contaminated soils which indicates the potential damage the battery wastes may cause to the surrounding environment (Abenchi *et al.*, 2010, Made *et al.*, 2015).

The mean concentration of cadmium in Akure 1, Akure 2 and Owo were above the control and the permissible limit (0.5 mg/kg). The high cadmium content in the studied area soil samples shows that the contamination level in the soil may pose a great hazard to microorganisms in the soil, plant productivity and animals that may be inhabiting such soil (Zeng *et al.*, 2015).

Conclusion

From the results obtained in this study, it is evident that the automobile battery wastes modify the physicochemical properties of the receiving soil and are direct sources of a number of heavy metals in such soil. Also, the results obtained in the study has lend credence to the fact that battery wastes are sources of Lead, Cadmium and Zinc in soil. Moreover, the low number and types of the bacteria isolated is an evidence that the battery waste adversely affect the microbial population in the receiving soil. Meanwhile, the array of microbial populations found on the soil samples may be used in the bioremediation protocol for the battery waste contaminated soil.

REFERENCES

- Abenchi, E. S., Okunola, O. J., Zubairu, S. M. J., Usman, A. A. and Apene, E. (2010). Evaluation of heavy metals in roadside soils of major streets in Jos metropolis. *Nigeria Journal of Environment and Chemical Ecotoxicology*, 2(6): 98-102.
- Ajai, A. I., Inobeme, A., Jacob, J. O., Bankole, M. T. and Olamoju, K. M. (2016). Determination of the Physicochemical and Heavy Metals Content of Soil around Selected Metalurgical Workshops in Minna. Ewemen, *Journal of Analytical and Environmental Chemistry*, 2(2): 78-83.
- Akinnibosun, F.I., Omonigho, S.E. and Oyetayo, M.A. (2020). Microfloral Composition Of Gastro-Intestinal Tract of Broiler Chickens Exposed To Feed Formulations From Fermented Cashew Apple Residue. *African Journal of Health, Safety and Environment* Vol: 1 (1): 64-72, 2020
- Amde, M., Liu, J.F. and Pang, L. (2015). Environmental application, fate, effects, and concerns of ionic liquids: a review, *Environ. Sci. Technol.* 49 (21): 12611–12627,

- Buxton, S., Garman, E., Heim, K.E. and Oller, A.R. (2019). Concise review of nickel human health toxicology and ecotoxicology, *INORGA* 7 (7): 89-90.
- CEC (2016). Environmentally sound management of spent lead-acid batteries in North America: Technical guidelines. Montreal: Commission for Environmental Cooperation; 2016 (in English, French & Spanish). Pp. 241-248.
- Dutta, T., Kim, K., Deep, A. and Yun, S. (2018). Recovery of nanomaterials from battery and electronic wastes: a new paradigm of environmental waste management, *Renew. Sustain. Energy Rev.* 82 (2): 3694–3704.
- Fan, E., Li, L., Wang, Z., Lin, J., Huang, Y. and Wu, F. (2020). Sustainable recycling technology for Li-ion batteries and beyond: challenges and future prospects, *Chem. Rev.* 120 (14): 7020–7063.
- Floch, C., Chevremont, A.C., Joanico, K., Capowicz, K. and Criquet, S. (2011). Indicators of pesticide contamination: Soil enzyme compared to functional diversity of bacterial communities via Biolog Ecoplates. *European Journal of Soil Biology*, 47(4): 256-263.
- Guo, X., Song, Y. and Nan, J. (2018). Flow evaluation of the leaching hazardous materials from spent nickel-cadmium batteries discarded in different water surroundings, *Environ. Sci. Pollut. Control Ser.* 25 (6): 5514–5520.
- Hartsock, N.J., Mueller, T.G., Thomas, G.W., Barnhisel, R.I., Wells, K.L. and Shearer, S.A. (2000). Soil Electrical Conductivity Variability. 5th international conference on precision Agriculture. ASA Misc. Publ., ASA, CSSA, and SSSA, Madison, WI. 23(9): 50-59.
- Kang, H.D., Chen, M. and Ogunseitan, A.M. (2013). Potential environmental and human health impacts of rechargeable lithium batteries in electronic waste, *Environ. Sci. Technol.* 47 (10): 5495–5503.
- Lee, K., Park, J.W. and Ahn, I.S. (2003). Effect of additional carbon source on naphtha lene biodegradation by *Pseudomonas putida* G7. *Journal of Hazardous Materials.* 105: 157–167.
- Liu, A. and Ren, X. (2020). 8 - power ready for driving catalysis and sensing: nanomaterials designed for renewable energy storage, in: Q. Zhao (Ed.), *Advanced Nanomaterials for Pollutant Sensing and Environmental Catalysis*, Elsevier. pp. 307–346.
- Mayyas, A., Steward, D. and Mann, M. (2019). The case for recycling: overview and challenges in the material supply chain for automotive li-ion batteries, *Sustain. Mater. Technol.* 19 (2): 8-17.
- Nwakife, C.N., Esther, U., Musah, M., Morah, E.J., Inobeme, A. and Andrew, A.1. (2022). determination of the physicochemical properties and some heavy metals in soils around selected automobile workshops in minna, Nigeria. 5(1): 69-81.
- Orjiakor, P.I. and Atuanya, E.I. (2015). Effects of automobile battery wastes on physicochemical properties of soil in Benin City, Edo State. *Global Journal Of Pure And Applied Sciences.* 21: 129-136.
- Pam, A. A., ShaAto, R. and Offem, O. O. (2013). Evaluation of heavy metals in soils around automobile workshop clusters in Gboko and Makurdi central Nigeria. *Journal of Environmental Chemistry and Ecotoxicology*, 5(11): 298-306.
- Shaikh, S., Thomas, K. and Zuhair, S. (2020). An exploratory study of e-waste creation and disposal: upstream considerations, *Resour. Conserv. Recycl.* 1(5): 10-12.
- UNEP (2003). Technical guidelines for the environmentally sound management of waste lead-acid batteries. Secretariat of the Basel Convention. Basel Convention series/SBC No. 2003/9. Geneva: Basel convention Secretariat; 2003.

Yang, G., Song, Y., Wang, Q., Zhang, L. and Deng, L. (2020). Review of ionic liquids containing, polymer/inorganic hybrid electrolytes for lithium metal batteries, *Mater. Des.* 190 (20): 108-115.

Zeng, X., Li, J. and Liu, L. (2015). Solving spent lithium-ion battery problems in China: opportunities and challenges, *Renew. Sustain. Energy Rev.* 52 (15): 1759–1767,

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