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Effects of Automobile Battery Wastes Disposal on Soil Health Indices

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study was designed to assess the impact of automobile battery waste 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 analyzed using standard methods while the heavy metal content was assessed using a spectrophotometer. Also, the microbial population was determined using the pour plate method and some biochemical tests. The results show that the soil sample from Owo had the least total bacterial count of 65.10x 10^5 CFU/g) while the sample from Akure 2 had the highest bacterial count of 185.50 x 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) was higher significantly ($p<0.05$) than the uncontaminated (0.21) soil sample.

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The pH values were acidic (4.57) compared with the control (7.42). Other indices like C, Ca. CEC and bulk density among others have values that were different significantly ($P<0.05$) between the contaminated soil and the control. In addition, the levels of heavy metals such as Lead, Cadmium and Chromium in the contaminated soil were significantly higher than in 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.

1. INTRODUCTION

In developing countries around the world, the issues about environmental pollution are 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, a high number of pollutants are discharged unabatedly into the environment [1].

Attention is usually focused on water and air pollution because 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 centred 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 [2].

Many times, mechanic workshops in Nigeria are situated in residential zones. The new policy of the government to pull the auto-mechanics, technicians and other forms of auto repair workers together in an automobile mechanic village is creating another environmental disaster. 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 daily all over the country.

The increase in the level of electronic waste as a result of battery waste disposal may become a big problem in the near future as the automobile industry is gradually transitioning to electromotive vehicles which are run on rechargeable batteries. The sale of these vehicles is estimated to be above thirty million units by come year 2030 [3]. The low economic value of recycling battery wastes on the one hand and the lack of proper regulation for the management of electronic wastes are the major contributing factors in the indiscriminate disposal of the battery wastes into the soil. The components of these wastes eventually will find their way into the water ecosystem where they are likely to cause serious damage to the biotic and abiotic components of the habitat [4].

Batteries are the main source of power for many devices and they are contributing significantly to the overall e-waste generated around the world. Components of these batteries are majorly made up of large amounts of heavy metals such as Mn, Cd, Pb and Li as well as other contaminants which are highly toxic to the ecosystem [5,6]. These heavy metals have been reported to cause impairments to various organ systems in the human body and disrupt reproduction, immunity as well and kidney functions as in the case of lead [7], and loosening of bone, damage to kidney and tumour development as in the case of cadmium.

Many of the new components of batteries especially those being included in electric vehicle production like ionic liquids, graphenes and oxides of metals are reported to be high-impact indicators of ecotoxicity [8]. Nonetheless, there is a dearth of information on the effect of these materials on the soil ecosystem as well as their effect on groundwater. Moreover, the storage devices for emerging energy sources may be more problematic to handle compared to the more known conventional ones [9]. 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.

2. MATERIALS AND METHODS

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 contaminant 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 solids (TDS), hardness, organic matter, C, N, P and moisture were determined using the method described by UNEP [10] and CEC [11].

Determination of minerals and heavy metals: The minerals and heavy metals present in the samples were assayed using the Atomic absorption 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 the pour plate technique. Molten nutrient agar, Salmonella- Shigella agar, Mannitol salt agar, MacConkey agar and Eosin Methylene Blue agar at 45 ^{0}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 ºC for 24 hours [12].

3. 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 x 10^5 CFU/g) which indicated that it is less contaminated among the tested samples. The sample from Akure 2 had the highest THBC value (185.50 x 10^5 CFU/g) followed by a sample from Akure 1 (154.33 x 10^5 CFU/g). Also, the HMRB ranged from 190.00 to 220.50 x 10^5 CFU/g with the Owo sample having the least and Akure 2 with the highest value against the control (94.33 x 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 (x 10^5 cfu/g)

Sample	THBC	HMRB
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 alphabet 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 a 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 [13].

Table 2 presents 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 [14]. The organic wastes might have helped in improving the soil aeration, thus providing adequate oxygen required by the microbial community which as a result favoured the growth of indigenous bacteria in the soil.

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 a high level of ionic liquid contamination of the soil samples. Earlier, Hartsock *et al.* [15] noted that

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, glistering	-	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

Table 3. 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}

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 the freeing up of their cathions in the soil.

The pH values obtained from the soil samples are quite acidic and lesser than the 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, the availability of nutrients can be affected by soil pH. This result agrees with the work of Orjiakor and Atuanya [16]. Earlier researchers like Pam *et al*. [17] and Ajai *et al*. [18] 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 have 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.* [19] submitted that metal cathion 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 differences (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 more prominent than the clay and silt in all the sampling sites. This is supported by the report from Nwakife *et al*. [20] where they obtained similar results for soil profile in polluted sites.

Carbon concentration was higher in the contaminated soil samples compared with the control soil sample while the nitrogen content was 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 the rainy season as well as the presence of microbial hydrolytic polyphosphates [19].

Fig. 1 presents the selected heavy metal content of battery waste polluted soil samples. The values of lead in the various sites were much higher than that of the control and the permissible limit (0.01 mg/kg) of WHO showed 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 automobiles which are usually lead-based electrolytes. This was similar to the work of Nwakife *et al*. [20] who also reported similar results.

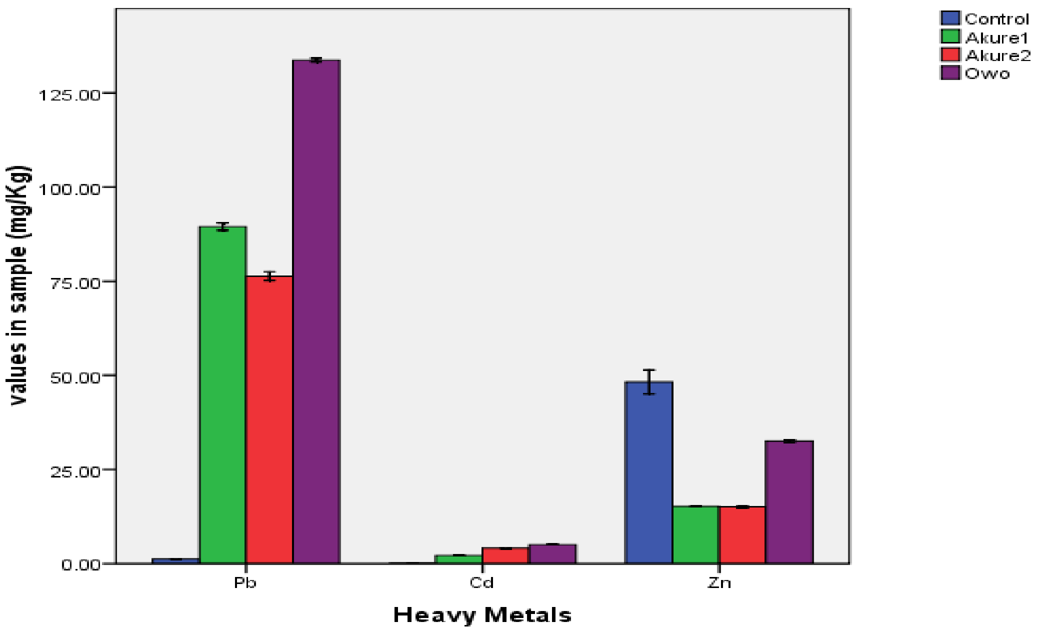

Fig. 1. Selected heavy metal content of battery waste polluted soil

The level of zinc in the contaminated soil samples as well as the control site were higher than the WHO permissible limit (5 mg/kg). Interestingly, the level of zinc was higher in the control than in 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 [21, 22].

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 [23,24].

4. CONCLUSION

From the results obtained in this study, it is evident that automobile battery wastes modify the physicochemical properties of the receiving soil and are direct sources of several heavy metals in such soil. Also, the results obtained in the study have 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 evidence that the battery waste adversely affects 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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