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RESEARCH ARTICLE

ALUMINUM WASTE CANS RECYCLING IN LAGOS STATE, NIGERIA: ANALYSIS OF SOIL AND WATER BENEFITS

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Abstract

The study empirically evaluated the environmental (water and soil) benefits of aluminum waste cans recycling in Lagos State, Nigeria. Soil samples were collected from three locations using a soil auger; the locations were aluminum at the recycling site, soil 100m away from the recycling site, and soil 150m away from the recycling site. From each location, three soil samples were collected and taken to the laboratory for analysis of soil physicochemical properties and heavy metal contents using standard methods. Similarly, a random sampling technique was employed to collect 3 borehole water samples 100m away from the recycling site and 150m away from the recycling site using 750 millimeters of a SMART plastic container. The collected water samples were taken to the laboratory for analysis of heavy metals using standard methods. The results obtained revealed that high contents of physio-chemical properties of OC (2.96%), Ca (10.92 cmol/kg), Mg (0.77 cmol/kg), K (0.24 cmol/kg), Na (0.57 cmol/kg), exchange acidity (0.33 cmol/kg) and ECEC (12.46 cmol/kg) were found in soil 100m away from the recycling site. Also high content of Av. P (23.27 mg/kg) was found in soil 150m away from the recycling. The contents of OC, P, Ca, Mg, K, and ECEC increase with distance away from the recycling site. No significant variations were found in the contents of OC, TN, P, Ca, Mg, K, Na, Al and ECEC ($p > 0.05$). The content of Fe (223.87 mg/kg) was found to be high at the aluminum waste cans recycling site (discharge point) and low in soil 150m away from the recycling site; while high Mn (2.62 mg/kg) content was found in soil 150m away from the recycling site and low in soil 100m away from the recycling point. The contents of Fe, Mn, Pb, Cd and Zn were with whom WHO maximum permissible level indicating low concentration in the soil. A negative and significant association was observed between Zn and Cd ($\rho = -0.812, p < 0.05$). High Fe (259.18 mg/L), Pb (2.49 mg/L) and Zn (16.01 mg/L) contents were found in the wastewater (discharge point), while high Mn (56.42 mg/L) content was found in the borehole water sample. The contents of Fe, Mn, Pb and Zn were the above WHO permissible limit. Based on the findings, the study concluded that the government should set up modalities to control the discharge of substances into the soil and water.

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Introduction:-

Aluminum is an integral part of our modern world because it is everywhere and is often in unsuspecting places. It is one of the most important metals used by modern societies. Multiple industries see this unique metal and its nearly infinite potential for reuse as a way to match the needs of corporations, governments, and the environment as they move towards a circular, sustainable future (Water, 2019). Aluminum carries immense versatility by being durable, increasing safety, yet lightweight enough to increase fuel efficiency (Water, 2019; OECD, 2010). World over, aluminum is the most-used metal after steel with a wide range of applications in the industrial field owing to its physical and mechanical properties (Yang et al., 2019). Aluminum has been recycled since the days it was first commercially produced and today almost one-third of the global aluminum consumption worldwide is contributed by recycled aluminum (Belinda, 2006). The aluminum can is by far the most recycled consumer beverage package globally by units, pounds and percentage recycled. It amounts to more than twice the recycling rate and recycled content percentages for beverage packages of other materials (Belinda, (2006). Aluminum makes a key contribution to fuel-efficient transportation as well as facilitates the construction of corrosion-resistant maintenance buildings.

Nigeria is one of the principal primary producers of aluminum (World Aluminum Report, 2020). Aluminum is a silver-white metal obtained from bauxite; the world's primary production of aluminum was 11,368 thousand metric tons in July 2020 (World Aluminum Report, 2020). In 2018, the size of the global aluminum market was 160 billion U.S. dollars. This market is expected to reach approximately 250 billion U.S. dollars by 2026 (Scerra, 2020). This goes to show the global importance of aluminum and its rising demand in the world market. Aluminum has to go through many different processes before it is transformed from its natural state to complete commercial production. As a result, the production of aluminum is costly and demands large quantities of energy (AlSaffar and Bdeir, 2008). Four tones of bauxite are needed to produce each tone of aluminum. Aluminum has a high scrap metal value and aluminum can be recycled by melting down and used to make similar products again (Spender, 2001). It is also extensively used in packaging for protection, storage, and preparation of food and beverages (Yang et al., 2019; Belinda, 2006). It can be rolled into ultra-thin foils which are light, and strong and have unique barrier and insulation qualities to preserve food and beverages against ultraviolet light, odour, and bacteria.

In Lagos State, despite the availability of recycling companies, aluminum waste cans among other solid wastes still remain a serious issue of environmental concern as a result of the indiscriminate disposal of aluminum can wastes. The inadequate provision of aluminum waste collection facilities cum management of existing facilities remains an immense environmental problem. The rapid pace of urbanization in the state would presuppose an increase in the provision of infrastructure to meet up with the daily rise in aluminum waste generation. This has not been the case, as Lagos State like other cities in Nigeria lack the infrastructure to properly manage the large volume of aluminum waste generated daily. The overwhelming volumes of aluminum waste generated and the absence of adequate waste management systems have the Lagos Waste Management Authority (LAWMA) unable to satisfactorily collect and dispose of aluminum waste among other solid waste across the State.

Aluminum waste disposal constitutes a major urban environmental paralysis in Lagos State and indeed a clog in the wheel of progress in terms of urban environmental purity and sanitation. The inadequacy in waste management facilities for proper collection and management of aluminum waste has hindered effective waste management. The effect of this is that most of the residents in Lagos State dump their wastes indiscriminately on the streets and along the expressways. Several studies have been carried out on the environmental consequences of indiscriminate waste dumping. In recent years in some Nigerian cities, the solid waste problem has been investigated from environmental, socio-political, economic, and spatial viewpoints (Kofoworola, 2007; Nzeadibe and Iwuoha, 2008; Ogbonna et al., 2012). Several other studies have examined the challenges of waste management practices (Agwu, 2012); while many others revolved around waste generation in households and industry (Wang et al., 2009) as major producers of waste. Studies have also been carried out on aluminum waste can recycling. Few of the available studies principally looked at the recycling of aluminum beverage cans from a descriptive perspective (Yang et al., 2019; OECD, 2010; AlSaffar and Bdeir, 2008; Belinda, 2006). Others looked at the environmental impacts of aluminum waste can recycling (Montana Department of Environmental Quality, 2004). These studies among others made little use of empirical data. Therefore, studies that assessed the environmental and economic benefits of aluminum waste recycling using empirical data (field data) have not been adequately documented in the literature on aluminum cans waste management and recycling. This paper examines the environmental and economic benefits of aluminum waste cans recycling in Lagos State. In particular, the paper examines the contributory benefits of aluminum waste can

recycling by comparing the conditions of the soil and water around aluminum waste can recycling those not undergoing recycling processes.

Materials and Methods:-

Study area

The study area is the 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 Agbowo-Ikosi, a town in the 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 in Lagos metropolis, owing in part to the increasing influx of people from Ikorodu's surrounding towns and villages attracted by the town's proximity to Lagos.

Data types

The following primary data types were used:

Data on the chemical characteristics of surface water (OC, TN, P, Ca, Mg, K, Na, Al, and ECEC).

Data on the heavy metal content of soil (Fe, Mn, Pb, Cd, and Zn).

Data on the heavy metal content of wastewater and borehole water (Fe, Mn, Pb, Cd, and Zn).

Sampling technique

This study basically made use of stratified and random sampling techniques. A stratified sampling technique was used to divide the study into three sites: recycling site, soil 100m, and soil 150m away from the recycling site. This approach enabled comparative analysis to be carried out and for the observed variation in soil chemical properties and heavy metal contents to be ascribed to the recycling activities as well as other human activities in the area. Thereafter, a random sampling technique was employed to determine the number of recycling companies to sample and the number of points to delineate for data collection. Random sampling technique was therefore used to select three (3) aluminum waste cans recycling companies in Lagos State. Soil samples were then randomly collected from three points on each of the recycling companies using a soil auger; since 3 recycling companies were selected, it, therefore, meant that 3 soil samples were randomly collected. Also, 6 soil samples were randomly collected, soil 100m and soil 150m away from the recycling site. In all, 9 surface soil samples were collected and taken to the laboratory for analysis. A similar approach was employed for the collection of surface water samples. In each of the selected recycling companies, boreholes were identified from which water samples were collected, while samples were also collected from aluminum wastewater. Unlike soil sampling, for water and wastewater sampling, only one sample was collected from recycling sites and compared with borehole water 100m away from the recycling sites. As such, 6 samples were therefore collected and taken to the laboratory for analysis.

Collection of soil and water samples

As already noted above soil auger was used to collect surface soil samples at a predetermined depth of 0 – 15cm. Soil samples were collected from two sampling points from the selected recycling companies. A similar approach was employed in the collection of soil samples from non-recycling sites. The collected soil samples were geo-referenced, stored in polythene bags, and properly labeled. They were then taken to the laboratory for analysis of physical, chemical, and heavy metal contents using standard methods. Water samples were collected from boreholes 100m away from the recycling and from aluminum wastewater in the recycling site using plastic containers. All containers were previously washed with detergent and finally rinsed with deionised water prior to usage. Before the water samples were collected, plastic containers were rinsed three times with sample water at the point of collection. The sample containers were labeled according to the location name. The collected water samples were immediately put in an ice bag cooler to maintain the required temperature and transported to the laboratory for analysis of chemical parameters using standard analytical methods (APHA, 1985).

Data Analysis

Data obtained from the laboratory analysis and administered questionnaire were analyzed using simple percentages, averages (mean), charts, Spearman's correlation, and a One-Way Analysis of Variance. The statistical analyses were performed with the aid of SPSS (Statistical Package for Social Sciences) Version 22.0 and Microsoft Excel Spreadsheet. The statistical tools to test the formulated hypotheses are as follows:

Results:-

Physical and chemical properties of soil

The result in Table 1 shows the physical properties of soils within the aluminum waste recycling site and those 100m and 150m away from the recycling point. The result showed that sand content ranged from 85.2 to 89.20%. The results showed that the aluminum waste cans recycling site comparatively had the highest sand content. The high sand content in the sampled soils suggests a decrease in organic matter. The sampled soils are principally sandy with sand accounting for more than 85% of the inorganic mineral fragment in the soil. This is so as the study area is a part of the coastal plain of southern Nigeria which is characterized by very sandy soils over wide expanses of land (Aweto and Enaruvbe, 2010). Also, the sandy nature of the soil is expected as the soils are derived from the same parent rock and are exposed to the same climate (Aweto and Enaruvbe, 2010). The content of silt was comparatively high in soil 100m away from the recycling site with a mean value of 10.07%. Across the studied soil, silt content ranged from 7.40 to 10.07%.

The concentration of silt in the studied soils suggests high silt contents which imply that the soils have a high water-holding capacity and the possibility of nutrient availability (Offiong and Iwara, 2011). High clay content was found in the soil 100m away from the recycling point, followed by the soil 150m away from the recycling point. This goes to show that clay content in the studied soils increases with distance away from the recycling point. It further goes to show that aluminum recycling results in the depletion of clay in the soil. Clay is involved in almost every reaction in soils which affects plant growth. Clay is noted to enhance soil water-retaining and nutrient-holding capacities (Aweto, 1981). The results in Table 1, therefore, show that soils 100m away from the recycling site have high contents of silt and clay.

Table 1:- Physical properties of soil across aluminum recycling and non-recycling sites.

Parameters	Recycling sites		
	Recycling site	100m away	150m away
Sand (%)	89.20	85.20	88.53
Silt (%)	7.40	10.07	7.40
Clay (%)	3.40	4.73	4.07

The result in Table 2 presents the results of the chemical properties of soils in aluminum waste cans recycling sites and those 100m and 150m away from the recycling point. The result showed that the content of organic carbon (OC) ranged from 0.27 to 2.97% with soil 100m away from the recycling site having high OC content (Table 2). The content of considerable varies across the studied soils. The high content of OC in soil 100m away from the recycling point is attributed to the high content of silt which favours the buildup of organic matter in the soil. This implies that soils 100m away from the recycling site have an abundance of OC than in disturbed soil. This is expected as recycling activities deprive the soil of organic wastes (wastes from tree leaves and other biodegradables) that favour OC accretion in the soil. This is consistent with the findings of Aweto (2013) that nutrient diminution is high and continues if woody trees are not fully established. For total nitrogen (TN), its content in the soils ranged from 0.04 to 0.06% with a slight increase found in the recycling point. Like OM, a high amount of N in the soil helps to improve soil quality and encourage agricultural productivity and sustainability (Aweto and Dikinya, 2003). The TN contents across the three soil categories indicate low concentration.

Like OC, there was a progressive increase in the contents of Av. P in the studied soils (Table 2). The contents of Av. P in the soil increased with distance away from the recycling site. The results showed that the highest Av. P concentration was found in soil 150m away from the recycling site with a mean value of 23.27mg/kg, followed by soil 100m away from the recycling site with a mean value of 14.19mg/kg. Low contents of topsoil Av. P was observed in the aluminum waste cans recycling site. The increase of Av. P in soils away from the aluminum recycling site may be associated with the high silt and OC contents in soils away from the recycling site. Generally, the result reveals a steady increase in the level of available phosphorus at a distance away from the recycling site. This could mean that aluminum waste cans recycling results in the dimulition of available phosphorus in the soil. The contents of exchangeable cations are shown in Table 2. The content of exchangeable calcium (Ca) increased with distance away from the recycling site. The result however showed that contents of Ca ranged from 2.99 to 10.92cmol/kg with soils away from the recycling sites having a high concentration. The increase in the level of organic matter may be responsible for the high Ca and Mg as well as K contents in soils distance away from the recycling site. In a related study, Mashi et al., (2015) attributed increased levels of Ca, Mg and K in the soil to

organic matter which raised the values of exchangeable cations. However, the critical values of exchangeable cations have been reported by various researchers. For instance, Adeoye and Agboola (1984) cited in Deekor et al., (2012) reported a critical value of 2.00cmol/kg for Ca. This figure when compared to the value obtained for the present soil shows high values for the studied soils.

Like Ca, the content of exchangeable magnesium (Mg) increased with distance away from the recycling site. The contents of Mg ranged from 0.27 to 0.77cmol/kg with soils away from the recycling sites having a high concentration. The result shows that aluminum recycling results in the depreciation or decline in Mg content in the soil. Adeoye and Agboola (1984) cited in Deekor et al., (2012) reported a critical value of 0.4cmol/kg for Mg. This figure when compared to the value obtained for the present soil shows a high value for soil 100m away from the recycling site. In addition, the contents of exchangeable potassium (K) and exchangeable sodium (Na) ranged from 0.14 to 0.24cmol/kg and 0.32 to 0.57cmol/kg respectively. High contents of K and Na were recorded in soil 100m away from the recycling point. Table 2 gives results on soil exchange acidity. The exchange acidity (Al^{3+}) value depth ranged from 0.20 to 0.33cmol/kg. It showed that the highest content of exchange acidity was observed in soil 100m away from the recycling point with a mean value of 0.33cmol/kg. The range of exchange acidity showed that these values were within the acceptable limits of 2.1 to 4.1cmol/kg (Holland et al., 1989).

In addition, the concentration of effective cation exchange capacity (ECEC) was high in soil distance away from the recycling site (Table 2). Across the studied soils, soil 100m away from the recycling site had the highest content of ECEC with a mean value of 12.46cmol/kg, followed closely by soil 150m away from the recycling site (4.27cmol/kg). The results simply indicate that ECEC in the studied soils showed a substantial increase in soils away from the recycling site. High ECEC value in soils away from the recycling site is attributed to the increase in organic matter in the soil. This is consistent with the findings of Hassan et al., (2016) cited in Chikere-Njoku (2019) that OM is a reservoir of soil exchangeable cations and favours the increases of ECEC in the soil. An increase in ECEC in fallow soils has been attributed to the buildup of organic matter (Aweto, 2013). The results in Table 2, therefore, reveal that the contents of OC, P, Ca, Mg, K., and ECEC increase with distance away from the recycling site.

Table 2:- Chemical properties of soil across aluminum recycling and non-recycling sites.

Parameters	Recycling sites		
	Recycling site	100m away	150m away
OC (%)	1.09	2.96	0.27
Total nitrogen (%)	0.06	0.04	0.04
Avail P (mg/kg)	11.41	14.19	23.27
Ca (cmol/kg)	2.99	10.92	3.54
Mg (cmol/kg)	0.27	0.77	0.37
K (cmol/kg)	0.14	0.24	0.16
Na (cmol/kg)	0.32	0.57	0.32
Acidity (cmol/kg)	0.22	0.33	0.20
Al (cmol/kg)	0.01	0.04	0.10

Variations in chemical properties

This part of the analysis determines the variation in the chemical properties of soil in aluminum waste cans recycling sites with those 100m and 150m away from the recycling site. The result revealed that only the content of acidity varied significantly among the studied soils, while no significant variations were found in the contents of OC, TN, P, Ca, Mg, K, Na, Al, and ECEC (Table 3). This implies that in spite of the comparatively high contents observed in soils away from the recycling site, the contents in the soil fall within the same range. This implies that the concentrations in soils away from the recycling site do not result in a substantial change in the chemical contents across the studied soils.

Table 3:- ANOVA result of the variation in chemical properties.

Parameters	Source of variation	Sum of Squares	df	Mean Square	F	Sig.
OC	Between Groups	11.466	2	5.733	.994	.424
	Within Groups	34.613	6	5.769		
	Total	46.079	8			

N	Between Groups	.000	2	.000	.411	.681
	Within Groups	.002	6	.000		
	Total	.002	8			
P	Between Groups	230.924	2	115.462	2.040	.211
	Within Groups	339.523	6	56.587		
	Total	570.447	8			
Ca	Between Groups	117.848	2	58.924	1.579	.281
	Within Groups	223.960	6	37.327		
	Total	341.808	8			
Mg	Between Groups	.423	2	.212	5.111	.051
	Within Groups	.248	6	.041		
	Total	.671	8			
K	Between Groups	.015	2	.008	.851	.473
	Within Groups	.054	6	.009		
	Total	.069	8			
Na	Between Groups	.123	2	.061	2.063	.208
	Within Groups	.179	6	.030		
	Total	.302	8			
Acidity	Between Groups	.031	2	.016	8.116*	.020
	Within Groups	.011	6	.002		
	Total	.042	8			
Al	Between Groups	.011	2	.005	.722	.524
	Within Groups	.044	6	.007		
	Total	.055	8			
ECEC	Between Groups	145.522	2	72.761	1.701	.260
	Within Groups	256.699	6	42.783		
	Total	402.221	8			

*Significant at 5% alpha level

Heavy metal content in the soil

The results of heavy metals are shown in Table 4. The result revealed that Fe content in the studied soils was high in the aluminum waste cans recycling site (discharge point) with a mean value of 223.87mg/kg, while low Fe content was recorded 150m away from the recycling site with a mean value of 77.57mg/kg (Table 4). The contents of Fe ranged from 77.57 to 223.87mg/kg. The apparently high Fe content in the waste cans recycling site is attributed to wastewater from aluminum waste cans recycling. The wastewater contains substances that increase the amount of Fe in the soil. This result agrees with the findings of Nazir et al., (2015) that attributed the increase in Fe content in the soil to industrial wastes and domestic discharge as well as natural geological sources. Similarly, Hong et al., (2014) stated that Fe in the soil could be from metal scraps in dump sites and the leaching of iron from iron smelting and fabrication from small-scale industries. The contents of Fe in the studied soils are within the maximum permissible level of 5000mg/kg set out by WHO which indicates low Fe pollution.

In addition, the mean concentration of Mn in the studied soils ranged from 1.66 to 2.62mg/kg with high Mn content found in soil 150m away from the recycling site, while low Mn content was found in soil 100m away from the recycling point. The concentrations of Mn in the studied soils are below the WHO permissible limit of 200mg/kg. The high Mn content in soil 150m away from the aluminum waste cans recycling site is attributed to industrial emissions, fossil fuel combustion, and effluents from household wastes. Also, the comparatively high value 150m away from the recycling site shows that Mn is abundant in the soils of the area. This agrees with the submission of

Rollin and Nogueira (2019) that manganese is ubiquitous in the environment, and human exposure arises from both natural and anthropogenic activities. More so, Barceloux (1999) stated that Mn occurs naturally in more than 100 minerals with background levels in soil ranging from 40 to 900 mg/kg, with an estimated mean background concentration of 330 mg/kg. The Mn values reported in the present study are far lower than the average values of 953.52mg/kg reported in Lagos (Oghuvwu, 2018).

Lead (Pb) mean the content was much higher in soil 150m away from the recycling site than in soil 100m away from the recycling site with mean values of 0.54 and 0.11mg/kg respectively. The Pb values in this study are far below the values reported in Lagos State by Olukanni and Adeoye (2012) with a range of 5.57 to 69.2mg/kg. The concentration of Pb in the studied soils is lower than the WHO permissible limit of 100mg/kg. However, the high content of Pb in soil 150m away from the recycling site is attributed to the diverse activities carried out in the area that result in the concentration of Pb in the soil. Atuanya and Oseghe (2006) noted that higher lead concentration in soils has a toxic effect on microorganisms inhabiting the soil which consequently alters the flora and fauna of a location. The study, therefore, shows that Pb concentration in the studied soils is low and has no toxic effects on biotic lives. In addition, cadmium (Cd) content in the soils ranged from 0.01 to 0.02mg/kg with comparatively high Cd mean value found in soil 150m away from the recycling site and low in the recycling site and 100m away from the recycling site. The Cd content reported in this study agrees with those reported in Lagos State by Anyakora et al., (2013) of 0.50 – 4.20mg/kg. The content of Cd in the sampled soils is lower than the WHO permissible limit of 0.8mg/kg. Cd content in the sampled soils is low implying the absence of Cd pollution in the soil and most especially at the aluminum recycling site. The mean content of Zn in the studied soils ranged from 3.05 to 6.48mg/kg. The concentrations of Zn in this study are within the range of 6.23 to 141.1mg/kg reported by Adesuyi et al., (2015) in Lagos State.

The result showed that high Zn contents were found in the discharge point and low in soil 100m away from the recycling site. It goes to show that the content of Zn tends to decrease with distance away from the aluminum recycling site. The variation in the concentration level of Zinc in these soils shows the impact of pollution from anthropogenic activities rather than lithogenic (Hong et al., 2014). Nevertheless, Zn contents in the respective soils are far below WHO 300mg/kg threshold for Zn concentration in the soil (Chiroma et al., 2014). It means that soils in the sampled soils have low Zn concentration, Hong et al., (2014) attributed the buildup of Zn in the soil to metal fabrication works and lubricating oil found as additives. The result in Table 4, therefore, shows that the contents of Fe, Mn, and Zn tend to be high in soil within the aluminum recycling site and reduce with distance away from the recycling site. It identifies aluminum waste cans recycling as the main human activity that generates and increases the contents of Fe, Zn, and Mn in the studied soils. It, therefore, means that aluminum waste cans recycling contributes to the input of metals in soil within the disturbed site.

Table 4:- Mean heavy metal contents in the studied soils.

Parameters	Recycling site	100m away	150m away	WHO limits
Fe (mg/kg)	223.87	182.88	77.57	500
Mn (mg/kg)	2.58	1.66	2.62	200
Pb (mg/kg)	0.28	0.11	0.54	100
Cd (mg/kg)	0.01	0.02	0.01	0.8
Zn (mg/kg)	6.48	3.05	6.07	300

Association between heavy metals

Here the association between heavy metals in the soil is examined. This was achieved using Spearman's correlation and the result obtained is presented in Table 5. The result showed that there was a negative and significant association between Zn and Cd ($\rho = -0.812, p < 0.05$); while a negative and insignificant association existed between Mn and Fe ($\rho = -0.033, p > 0.05$), Pb and Fe ($\rho = -0.467, p > 0.05$), Cd and Fe ($\rho = -0.159, p > 0.05$), Cd and Mn ($\rho = -0.494, p > 0.05$) and Cd and Pb ($\rho = -0.360, p > 0.05$). A similar negative association between Zn and Cd was reported by Hao et al., (2011) in their study of the distribution and bioavailability of Cd and Zn in cultivated soil of Henan Province. The negative correlation coefficients imply that increase in a metal's content will result in a corresponding decrease in another metal. For instance, an increase in the content of Zn in the soil will bring about a corresponding decrease in the content of Cd. This also applies to other metals with negative correlation coefficients. The result also showed that positive and insignificant association existed between Pb and Mn ($\rho = 0.350, p > 0.05$), Zn and Fe ($\rho = 0.050632, p > 0.05$), Zn and Mn ($\rho = 0.567, p > 0.05$) and Zn and Pb ($\rho = 0.533, p > 0.05$). The positive correlation coefficients entail that an increase in a metal will result in an increase in another metal and vice

versa. For instance, an increase in the content of Pb in the soil will bring about a corresponding increase in the content of Mn. This applies to other metals with positive correlation coefficients. The positive association between the variables implies that they are probably influenced by similar anthropogenic and natural factors, while the negative associations mean that the various variables are not influenced by similar anthropogenic and environmental factors (Iwara et al., 2012).

Table 5:-Zero-order correlation matrix.

Metals	Fe	Mn	Pb	Cd	Zn
Fe	1				
Mn	-0.033	1			
Pb	-0.467	0.350			
Cd	-0.159	-0.494	-0.360	1	
Zn	0.050	0.576	0.533	-0.812	1

*Correlation is significant at the 0.05 level (2-tailed).

Heavy metal content in water

The heavy metal contents in aluminum waste cans recycling wastewater and borehole water within the recycling site are presented in Table 6. The mean concentration of iron (Fe) in the discharge point (recycling wastewater) and the borehole was 259.18 and 255.05mg/L respectively. It shows that Fe content is comparatively higher in wastewater than in borehole water. Fe contents in the recycling wastewater and borehole are above the WHO permissible limit of 0.3mg/l (Njar et al., 2012; Nwankwoala et al., 2016) which indicates Fe pollution. The high concentration of Fe suggests water from the borehole in the study area has the likelihood of affecting laundering as well as upsetting the human system. The generally high concentrations of Fe in the borehole also entail it can cause adverse effects on humans within the vicinity. According to Oyem et al., (2015), the use of groundwater for drinking in many cases is limited by the presence of dissolved iron and to a lesser extent manganese. The complex nature of human activities such as the commercial activities of automobile mechanics and iron/metal works artisans, and carcasses of abandoned and unserviceable cars among several are some of the anthropogenic activities that could be attributed to the high Fe. It also goes to show that Fe is abundant in the area and needs to be controlled. In line with this, Ngah and Nwankwoala (2013) stated that the occurrence of iron may rather be related to the geological history and source rocks of the deposits that constitute the aquifers in the Niger Delta. This is because the aquifers are predominantly sands with thick brown coloration due to iron oxide coatings and stains (Ngah and Nwankwoala, 2013). This reason among other available anthropogenic activities in the area is responsible for the high Fe content in the sampled borehole.

Manganese like iron is a secondary-priority chemical contaminant (Oyem et al., 2015). Like Fe, they are abundant on the earth's surface. The mean content of Mn (manganese) in the recycling wastewater was 1.27 mg/L, while the high mean value for the borehole was 56.42mg/L. The mean content of Mn for recycling wastewater and borehole are above the WHO desirable limit of 0.5mg/L (Nwankwoala et al., 2016). The comparatively high concentration of Mn in the borehole sample means it would not have good taste and would promote the growth of algae in reservoirs or collection tanks (Njar et al., 2012). Its high content indicates a natural hydrogeologic factor rather than anthropogenic because like Fe, it is an abundant element. Mn is a very important constituent trace metal in the tissues of all living organisms. In our surrounding environment, Mn is frequently found in metamorphic, sedimentary, and igneous rocks. Its average content in the lithosphere is about 1000 ppm (Nwankwoala et al., 2016). The high content of Mn in the borehole water sample is also attributed to municipal and industrial wastes in the area. The effluents from these sources, mostly poor septic systems, resulted in the increase of Mn. The high contents of Fe and Mn in the studied wastewater and borehole samples are expected. This is because iron and manganese are common elements in the earth's crust and as water percolates through soil and rock it can dissolve these minerals and carry them into groundwater (Foster, 1985 cited in Moyosore et al., 2014). The findings suggest that groundwater sources in the area are prone to high Fe and Mn concentrations from soils around their area. Iron (Fe) and manganese (Mn) are metallic elements present in many types of rock and are commonly found in water (Moyosore et al., 2014).

Zinc is a very common substance that occurs naturally. Many foodstuffs contain certain concentrations of zinc. Drinking water also contains certain amounts of zinc, which may be higher when it is stored in metal tanks. Zinc (Zn) mean contents in the wastewater sample and borehole were 16.01 and 3.19mg/L respectively and happened to be above the WHO allowable limit of 3.0mg/L for drinking water (Nwankwoala et al., 2016). This indicates that the

groundwater sources contain a high proportion of Zn. The high concentration further implies that the borehole water sources in the area have a caustic taste, hence may not be ideal for consumption and other domestic uses. Zinc is an essential element for the life of animals and human beings. It is also essential for male reproductive activities. Zinc is widely distributed in the body –in bones, teeth, hair, skin, liver, muscle, white blood cells, and testes (Nwankwoala et al., 2016). Thus, the high concentration also implies the borehole sources are not good for domestic uses.

Lead occurs naturally in the environment. However, most lead concentrations that are found in the environment are a result of human activities. Lead enters (drinking) water through the corrosion of pipes. This is more likely to happen when the water is slightly acidic. The distribution of lead in the environment varies from place to place. Lead occurs in drinking water through leaching from lead-containing pipes, faucets, and solder joints frequently found in the plumbing of older buildings. Lead may be found in and around workplaces where lead is used as well as in waste materials from production processes. The study further revealed that the contents of Pb and Zn were comparatively high in the discharge point (wastewater) and low in the borehole water, while the contents of Cd were within the same range in the two studied locations. The values of Pb and Zn were above the WHO permissible limits indicating the presence of metal pollution in the wastewater and borehole water. The results of this study indicate that there is considerable lead pollution in the water samples, since natural unpolluted water systems usually have low lead levels (Makokha et al., 2008).

Table 6:- Mean heavy metal contents in wastewater and borehole water samples

Parameters	Recycling site	Borehole	WHO limits
Fe (mg/L)	259.18	255.05	0.3
Mn (mg/L)	1.27	56.42	0.5
Pb (mg/L)	2.49	1.66	0.01
Cd (mg/L)	0.03	0.03	0.003
Zn (mg/L)	16.01	3.19	3.0

Conclusion and Recommendations:-

The study has shown that aluminum waste cans recycling has both positive and negative effects on the environment. However, from the findings, the positive gains exceed the negative effects. The study reveals that the contents OC, Ca, Mg, K, Na, exchange acidity, and ECEC are comparatively high in soil with a considerable distance away from the recycling site. This goes to show that apart from the perceived environmental gains of recycling, aluminum waste cans recycling results in the decline of essential soil chemical properties. This is expected as the recycling site lacks adequate trees and grasses and other forms of organic inputs which affect the buildup of nutrients in the soil. On the contrary, the study shows that aluminum recycling in the area does not negatively impact the metal content of the soil. This is shown by the low contents of metals in the soil of the recycling site. The study further reveals that the recycling activities as well as other human activities carried out in the area result in the high concentration of metals in the borehole water samples found around the recycling site. This is so because the aluminum wastewater causes a substantial increase in heavy metal contents of borehole water and their concentrations are found to be above WHO permissible limits. This goes to show that the borehole waters around the recycling site are not ideal for human consumption and can pose a serious threat to people's health in the area. It, therefore, calls for the proper monitoring of activities basically anthropogenic to control the extent of metal pollution in the area. Based on the research findings, the study recommends that the contents of Fe and Mn should be regularly monitored by government agencies because their concentration in the borehole water is worrisome and can have health effects on the people. It also recommends that the fertility status of the soils 100m away from the recycling site should be conserved through the planting of trees in the area. The planting of trees will help in increasing and conserving the fertility level of the soil.

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