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Physicochemical Assessment of Soils from Selected Metal Scrap Dumpsites in Anambra State, Nigeria

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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

Soils are prone to pollution due to the influence of climate change, globalization and industrialization. Soil samples used in this research were collected from two different metal scrap dumpsites while the controls were taken 500m away from sampling sites all in Anambra state, Nigeria. The physico-chemical parameters analyzed were pH, electrical conductivity, total organic carbon (TOC), moisture content, nitrate, phosphate and heavy metals. Heavy metals viz: Cd, Co, Fe, Mn, Pb and Zn concentrations (mg/kg) were determined using Varian AA240 model of atomic absorption spectrophotometer (AAS). The pH and electrical conductivity determinations were done in situ using Searchtech, PHS-7010 multimeter scale. Moisture content of the samples were determined in DHG-9053A oven. The soil samples in the studied areas contained Cd, Co, Fe, Mn, Pb and Zn. The analysed heavy metals concentrations were attributed to anthropogenic sources and geological formation of the areas since the control samples equally had appreciable concentrations of some of these heavy metals. The pH, EC, salinity, nitrate and phosphate values obtained in this study pose no harm on the soils yet. However, the concentrations of some heavy

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metals assayed are significantly higher than WHO permissible limit for heavy metals on soils. Therefore, good management of metal scrap activities is highly recommended in Anambra State since metal scrappers occupy most large vacant lands near farm lands, water bodies and human settlements thereby increasing the potency of toxic chemicals in the ecosystem.

Keywords: Soil; metal scrap dumpsites; pollution; heavy metals; AAS; WHO.

1. INTRODUCTION

Soils are exposed to pollution due to the influence of climate change, globalization and industrialization [1]. With rapid urbanization and industrialization, the environment is severely contaminated by heavy metals and their rates of transfer in the soil, water and air have continued to increase till date [2]. Crude oil which contains both inorganic and organic compounds is known to cause environmental pollution through its exploration, production, transportation and oil spillage activities. Soil contamination with high concentration of pollutants may affect the microorganisms living in the soil [3].

Soil is a major component of agricultural food production and it serves as the source and/ or sink for toxic substances [4].

One of the major challenges confronting Nigeria as a country is solid waste management [5]. Municipal solid wastes are routinely deposited on the roads, drains, water bodies and uninhibited lands. Metal scrap is one of the municipal solid wastes (MSW), which have monetary value in Nigeria [6]. The scrapyards are haphazardly sited in rural and urban centres in Nigeria where all kinds of scraps from abandoned automobiles, machineries and electrical appliances are disassembled [7]. Many of these scrap materials contain contaminants such as heavy metals, polycyclic aromatic hydrocarbon and other toxic substances that adversely affect the ecosystem [8]. Human beings may be exposed to these toxic substances through inhalation, ingestion or dermal contact [9]. Heavy metals present in solid municipal wastes via interaction with soil components, bio-accumulate and persist in soil and consequently go into the food chain and consumed by human [10].

The increased level of metals that accumulate in the soil and affect nearby ecosystems primarily originates from anthropogenic activities such as discharge of industrial and domestic wastes, mining, smelting operations and vehicular emission [11]. Weathering of the natural rock is another known source of heavy metal pollution in soils. However, input of metals from human sources in soils is higher than the input from natural sources [12].

Heavy metals are released into the environment from metal smelting and refining industries, scrap metals, plastic and rubber industries, various consumer products and from burning of waste containing these elements. The metals volatilize on burning and is released into the air. These volatilized metals become mobile and travel long distances to deposit on the soil, vegetation and water depending on their density [13]. The deposited metals are non-degradable and persistent in the environment and pose severe poisoning on humans through inhalation, ingestion and skin absorption. Acute exposure to these toxic metals leads to nausea, anorexia, vomiting, gastrointestinal abnormalities, dermatitis and many fatalities. The contamination of the ecosystem by heavy metals is a serious problem in the society because the environment is a direct receptacle for waste products generated in the space within the environment [14]. Meanwhile, zinc and copper are some essential nutrients to humans and animals for biochemical activities [15]. Waste from municipal dumpsites bear soils that are satisfactorily rich in organic matter that would be acceptable for surface feeder plants [16]. It was reported that open dump sites perform a twofold purposes of a safe disposal of waste and simultaneously improve chemical properties of soils that constitute productive agricultural fields [13].

Nigeria has a comparatively very poor waste management approach [17]. Indiscriminate waste dumps and scrap dumpsites occupy almost every vacant plot of land especially along major roads and streets. It is suspected that these activities contaminate and degrade the soil by causing substantial alteration of the physical and chemical composition of the soil hence compromise efficient and quality plant growth.

Thus, the inadequate waste management approach has the potential of increasing soil metal concentration in and around Anaocha and

Njikoka major scrap dumpsites. The mobility of heavy metals, bioavailability and related bio-toxicity to organisms depend on their specific chemical forms or ways of binding and the total metal concentration obtained after strong acid digestion.

Presently, there is no information regarding the assessment of inorganic and organic compounds in soil around the metal dumpsites in the studied areas. It is hoped that the present study would produce a new framework for assessment of environmental risks associated with metal scrap dumpsite activities. Therefore, this study seeks to assess the physicochemical properties and heavy metals (Cd, Co, Fe, Mn, Pb and Zn) in the vicinity of open waste dumpsite at Adazi-ani (Anaocha) and Abagana (Njikoka) areas in Anambra state, Nigeria. Assessment of these soils followed a thorough soil chemistry as well as comprehensive laboratory work to fully comprehend the extent of contamination of the environment and the potential risk to the ecosystem.

2. MATERIALS AND METHODS

2.1 Description of Study Area

Adazi-ani is a community in Anaocha local government area while Oyeagu is situated at Abagana, in Njikoka local government area, both in Anambra state, Nigeria. They are in between Awka and Nnewi metropolis. The areas are located in the Niger Delta Basin. Adazi-ani metal scrap dump site lies on latitude 6.07304^{0}N and longitude 6.982019^{0}E while Abagana metal scrap dumpsite lies on the latitude6.18502^{0}N and longitude 6.95646^{0}E. Adazi-ani control coordinates at 6.080008^{0}N and 6.987892^{0}E while that of Abagana at 6.187943^{0}N and 6.970761^{0}E.

2.2 Soil Sampling and Analysis

Total of eight (8) soil samples were used in this study. Soil samples used in this research were collected with a soil auger at 0-15cm depth and 15-30 cm depth from the metal scrap dumpsites and controls collected 500m away from sampling sites. The pH was determined in -situ using pH meter. The samples were put in sealed plastic bags, labelled and conveyed to the laboratory. After moisture content determination, the soil samples were air dried, crushed and passed through a 2mm sieve prior to other analysis. Samples for heavy metals were digested using aqua regia method and finally analysed using Varian AA240 atomic absorption spectrometer (AAS) at Spring Board Research Laboratories, Awka, Anambra state, Nigeria. The average and standard deviation obtained from duplicate analysis of the samples were compared with WHO permissible limits.

2.3 Soil pH and Conductivity Determination

The soils pH and conductivity were determined using a calibrated Searchtech, PHS-7010 multimeter by adopting the method described by AOAC 2012 [18]. The meter was first standardized against standard buffer solutions of known pH values according to the manufacturer’s instruction. The electrodes of the meter were then washed with distilled water and then immersed in the samples contained in a beaker. The pH and electrical conductivity of the samples were then read on the multimeter scale and noted.

2.4 Moisture Content Determination

By adopting the modified method described by AOAC 2012 [18], 2g of each sample was weighed into Petri dishes that were washed and dried in an oven. The weight of the Petri dishes and samples were noted before drying. The Petri dishes and samples were transferred into DHG-9053A oven and heated at 105^{0}C for 3hrs, cooled in desiccators and the weight was noted. The drying procedure continued until constant weights were obtained.

% moisture content= W2-W3/W2-W1×100/1

Where:
W1= weight of the crucible
W2= weight of the crucible+ sample before drying
W3= weight of the crucible+ sample before drying.

2.5 Nitrate and Phosphate Determination

Nitrate and phosphate concentrations of the soils were determined following the procedure used by Onoyima and Okide [19].

2.6 Heavy Metals Assay

The samples for heavy metals analysis were digested using aqua regia method and the digests were assayed using Varian AA240 atomic absorption spectrometer (AAS) and the duplicate data obtained were subjected to statistical calculations.

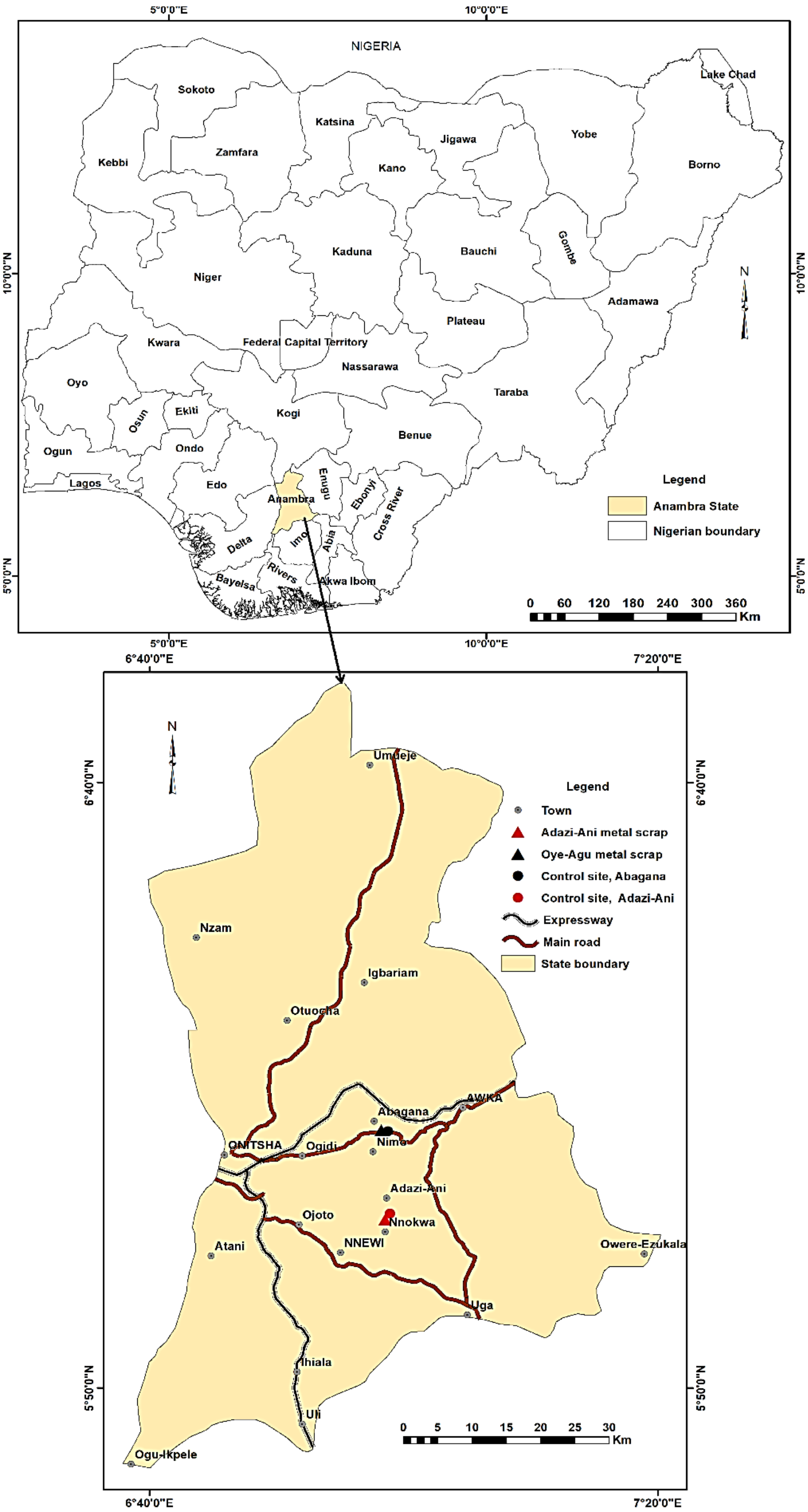

Fig. 1. Map of Anambra State, showing the study areas

3. RESULTS AND DISCUSSION

According to Table 1, the results showed that the pH values of the soils are alkaline except for AC15 which has a neutral value of 7.78. The pH values obtained in this study is higher than the prescribed limits of 6.5-7.5 [19]. Plants may not thrive in acidic (low pH) soils. Salinity values of the analysed soils were within the limit. Salts reduce the soils water holding capacity. A soil

Table 1. Results of physicochemical parameters of the soil

Samples ID	pH	EC.(dS/m)	Moist cont (%)	TOC (mg/kg)	Salinity (dS/m)	Nitrate (mg/kg)	P(mg/kg)
AD0	8.23	-54.00	3.50	14.58±0.12	0.20±0.01	6.62±0.17	2.32±0.03
AD15	8.30	-57.00	2.50	26.52±0.25	0.28±0.05	6.45±0.02	3.28±0.76
AC0	8.43	-43.00	3.00	14.31±0.12	0.86±0.82	4.55±0.36	2.29±0.04
AC15	7.78	-8.00	2.00	9.39±0.53	0.40±0.03	8.43±0.20	3.07±0.93
OD0	8.07	-42.00	1.00	23.66±0.43	0.60±0.06	5.86±0.60	2.38±0.06
OD15	8.48	6.70	52.00	28.45±0.24	0.24±0.27	5.44±0.57	2.05±0.06
OC0	8.53	-57.00	4.50	14.07±0.06	0.36±0.05	6.14±0.32	2.30±0.13
OC15	8.42	-62.00	2.50	9.39±0.53	0.41±0.02	6.51±0.04	2.91±0.77

AD0 and D15 =Adazi-ani dumpsite 0-15cm and15-30 cm respectively, AC0 and C15= Adazi-ani control 0-15cm and15-30 cm respectively, OD0 and D15= Oyeagu dumpsite 0-15cm and 15-30cm respectively, OC0 and C15 =Oyeagu control 0-15cm and 15-30cm respectively, ID= identity, EC. = electrical conductivity, moist cont= moisture content, TOC=total organic carbon, P = phosphate

Table 2. Concentrations (mg/kg) of metals from all depths(cm) and locations

Samples ID	Lead	Cadmium	Zinc	Manganese	Cobalt	Iron
AD0-15cm	0.103±0.017	0.154±0.036	1.940±0.005	0.021±0.014	0.006±0.006	8.158±9.421
AD15-30cm	0.057±0.012	0.062±0.014	1.842± 0.007	0.007±0.000	0.005±0.007	1.151±0.035
AC0-15 cm	0.369±0.132	0.413±0.077	1.517±0.158	0.013±0.000	0.011±0.004	0.192±0.098
AC15-30cm	0.013±0.012	0.027±0.001	0.301±0.010	0.004±0.006	0.006±0.008	0.320±0.010
OD0-15cm	0.028±0.003	0.015±0.002	1.480±0.016	0.011±0.007	0.014±0.002	0.747±0.044
OD15-30cm	0.046±0.009	0.021±0.000	1.843±0.008	0.009±0.002	0.000	1.109±0.064
OC0-15cm	0.010±0.003	0.020±0.004	0.101±0.115	0.010±0.002	0.000	0.244±0.004
OC15-30cm	0.008±0.009	0.012±0.001	0.149±0.000	0.007±0.003	0.006±000	0.295±0.016
WHO limit	0.01	0.003	3.00	0.50	0.03	3.00

AD0 and D15 =Adazi-ani dumpsite 0-15cm and15-30 cm respectively, AC0 and C15= Adazi-ani control 0-15cm and15-30 cm respectively, OD0 and D15= Oyeagu dumpsite 0-15cm and 15-30cm respectively, OC0 and C15 =Oyeagu control 0-15cm and 15-30cm respectively, WHO limit= world health organization limit that is salty can be wet and yet lack water for plant growth. This is because salts have a strong attraction for water molecules that the roots cannot overcome it. The salt content of a soil can be estimated from the electrical conductivity of the soil measured in a saturated soil paste [20]. Soil salinity occurs when the electrical conductivity (EC) of the saturation extract (ECe) in the root zone exceeds 4dS/m at 25^0C [21]. Moisture content of all the soil samples were within the range of 2-4% but OD015 significantly have 52%. Higher moisture content of 20-40% shows poor soil aeration. It was observed that the dumpsite recorded the highest value (28.455) while the least value (9.390) occurred in a control sample. The organic carbon content (TOC) of the soils were greater than 0.7% and thus revealed that the soil would be fertile for agriculture in case if the scrap activities discontinued [22]. The nitrate and phosphate content of the soils were higher than the values obtained in the literature [19].

From Table 2, the heavy metal analysis revealed that AD0, AD15, OD0, OD15, OC15 have higher concentration of lead, AC15 has the value (0.008mg/kg) which is lower than WHO recommended limit while OC0 and AC15 values are within WHO permissible limit of (0.01mg/kg). The average values of Cd in all the soil samples exceeded 0.003mg/kg recommended by world health organization standard for agricultural soils [23,24]. The mean concentrations of zinc, manganese and cobalt in all samples were found to be within the WHO permissible limit. The concentration of iron in all the soil samples were within the threshold except for AD0 whose value (8.1580mg/kg) is far above the WHO permissible limit [25,26].

4. CONCLUSION

The soil samples in the studied areas contained Cd, Co, Fe, Mn, Pb and Zn. The analysed heavy metals concentrations were attributed to anthropogenic sources and geological formation of the areas since the control samples equally had appreciable concentrations of some of these heavy metals. The pH, EC, salinity, nitrate and phosphate values obtained in this study pose no harm on the soils yet. However, the concentrations of some heavy metals assayed are significantly higher than WHO permissible limit for heavy metals on soils. Therefore, good management of metal scrap activities is highly recommended in Anambra State since metal scrappers occupy most large vacant lands near farm lands, water bodies and human settlements thereby increasing the potency of toxic chemicals in the ecosystem.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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