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RESEARCH PAPER

Effect of municipal waste dumpsites on chemical properties of soils in Southeastern Nigeria

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Abstract

A field study was conducted to determine the effect of dumpsites on the chemical properties of soils in four locations in Imo (Umuna and Okigwe) and Abia (Isuikwuato and Umuahia) States both in Southeastern Nigeria. Soil samples were collected from the dumpsites at 0-20 and 20-40 cm depth which were used to compare with those of their adjacent open sites (AOS) 25 meters away from the dumpsites. Changes in the soil chemical properties were observed to give an insight of the amount of nutrient added due to the refuse dump. The dumpsites in both Imo and Abia increased the chemical properties of the soils, and there were significant differences (P<0.05) between the values of the dumpsites and the adjacent open sites. However, the values of the elements; pH, organic carbon, total nitrogen and available phosphorus in the dumpsites were significantly higher (P<0.05) than those of the adjacent open sites. For example, the soil pH values in Umuna Imo State and Umuahia in Abia State were raised from 4.7 to 7.6 and 4.9 to 8.2, respectively as a result of the influence of the dumpsites. Also when compared with the adjacent open sites, the dumpsites significantly increased the exchangeable bases (Ca++, Mg++, K+ and Na+), effective cation exchange capacity (ECEC), percentage base saturation and reduced the exchangeable acidity of the soils in both locations at 0-20 and 20-40 cm depth.

Key Words: Dumpsites, Chemical properties, Soils, Abia and Imo States

Introduction

Solid wastes resulting from household (garbage), industrial and commercial production, constitute the greatest environmental threat to the urban population. The problems of solid wastes generation and refuse dumpsites have remained intractable urban problem because of the volume and range of solid wastes generated daily in the cities of Nigeria (Anijah–Obi, 2001; Essien and Hanson, 2013).

Refuse dumpsites contribute in no small measure to the pollution of both surface and ground water. Burning of refuse at the dumpsites resulted in atmospheric pollution and also affected the chemical properties of the soil by reducing the nutrient availability (Orji, 1994). In most developing countries like Nigeria, open refuse dumpsites are the only available option for waste disposal (Nta and Odiong, 2017). The wastes are sometimes used to fill land depression such as land already excavated and valleys.

Solid wastes found at refuse dumpsites are in two major categories: Industrial solid wastes as well as domestic solid wastes. Industrial solid wastes are waste materials generated in the course of manufacturing process. They include metal scraps, chips, pieces of glass, etc., while domestic wastes on the other hand are the by-products of household activities and consumption (Orji, 1994).

With agriculture as the mainstay of most economics of developing nations, and the proliferation of urban and semi-urban areas, waste dumpsites are becoming attractive because of their rich, deposits of organic matter and plant nutrients if properly handled and disposed. The evaluation of the dumpsite for its capability of containing adequate soil nutrients has been given less attention in the tropics. However, Anikwe and Nwobodo (2001) opined that these wastes end up interacting with the soil system thereby changing the physical and chemical properties. The authors also added that the municipal waste increases the content of soil organic matter, nitrogen, pH, cation exchange capacity and percentage base saturation. Therefore, the need to examine the effect of refuse dump on soil chemical properties as well as possible ways of managing these wastes in Imo and Abia States becomes necessary.

Materials and Methods

General Description of the Study Sites

The study was conducted on dumpsites in two states Viz: Imo and Abia states. This study areas are located on latitude 0.5° 29' N and longitude 07° 33' E in the rainforest ecological zone of South Eastern Nigeria and lies at a mean elevation of 122 meters (400 ft) above sea level (climatic data for National Root Crops Research Institute (NRCRI) Station, Umudike, 2018). Geographically, South Eastern Nigeria refers to the area bounded within latitude 4° 20″ and 7o 24″ North of the equator and longitudes 5o 25″ and 8° 51″ East of the Greenwich meridian, occupying a land area of about 109,524 sq. Km or about 11.9% of the total land area of Nigeria (Odurukwe et al., 1995). Temperatures of the study sites are generally high, ranging from 260C to 280C, and the highest temperature is experienced between January and February. The mean annual rainfall varies from 2000mm in the Northern zone to 3500mm along the coast which both Imo and Abia states belong (Odurukwe, et al., 1995).

In Imo state, the dumpsites were located in Umuna and Okigwe. The dumpsites had been in use by the people living around the metropolis, especially the traders, since they were situated adjacent to the market. Also, the dumpsites had been there for over twelve (12) years. The dumpsites in Abia State were located at Amaba in Isuikwuato Local Government Area and Umuahia along Aba Port Harcourt express road. They were open dumpsites which had been there for over fifteen (15) years.

Soil samples were collected in the selected waste open dumpsites. The soil samples were collected at 0-20cm and 20-40cm depth using soil auger. The samples were also collected in the adjacent open site (AOS) at the same depths, 25 meters away from the dumpsites.

The soil samples were air-dried, crushed and sieved through a 2-mm sieve and later taken to the laboratory for chemical analysis. The procedures that were used for these determinations were outlined below:

Soil chemical analysis

- Soil pH, organic carbon (OC), organic matter (OM) and total nitrogen (N) were determined according to McLean (1982), Nelson and Sommers (1982), Allison (1965) and Bremner (1965), respectively.

- Exchangeable Bases

Calcium (Ca) and magnesium (Mg) were determined by the complexometric titration method described by Chapman (1965). Sodium (Na) and potassium (K) were determined from 1N ammonium acetate (NH4 OAC) using the auto electric flame photometer (AOAC, 1970).

- Exchangeable Acidity (EA)

Exchangeable acidity (H+ and Al3+) was determined using the titrimetric method of McLean (1965). The Effective Cation Exchange Capacity (ECEC) was determined by calculation. (ECEC = ∑ bases + KCl – extractable (Al + H) values).

- Base Saturation (BS)

Percentage base saturation (BS) was calculated by multiplying total exchangeable bases (TEB) by 100 and dividing by the corresponding cation exchange capacity value.

$$\text{Percentage base saturation} = \frac{TEB \times 100}{CEC}$$

- Available Phosphorus (P) was determined by the Bray and Kurtz (1945) extractant method – Bray's Method 11. The ppm phosphorus was determined using a photo-electric calorimeter (Page et al., 1982).

Statistical analysis

The data collected were analyzed statistically using analysis of variance (ANOVA) and significant differences between treatment means of various experiments were tested at $P \leq 0.05$ using the Fisher's least – significant differences (F – LSD) according to Steel and Torrie, (1980).

Results

Effect of dumpsites on soil chemical properties

Tables 1 and 2 summarize the effect of municipal waste dumpsites on organic carbon, organic matter, total nitrogen, pH and available phosphorus of the soils in Abia (Isuikwuato and Umuahia) as well as Imo (Umuna and Okigwe) at 0 – 20cm and 20 - 40 depths. There were significant changes observed in these elements as a result of the refuse deposited in the sites. However, the values of these elements; pH, organic carbon (OC), total nitrogen (N) and available phosphorus (P) in the dumpsites were significantly higher ($p<0.05$) than those of the adjacent open sites.

Some increases in the pH of soils in the dumpsites were observed in the four locations in Abia and Imo States at the depths of 0 – 20 and 20 – 40 cm. The pH of the dumpsites in Abia and Imo were slightly alkaline with mean values of 7.7 and 7.1, whereas their adjacent open sites were found to be medium acid with mean values of 4.7 and 4.6, respectively at 0-20cm depth (Table 1). Similarly, the pH values of soil depth of 20-40 cm (Table 2) followed the same trend. Also observations were made in the organic carbon and organic matter status of both sites. The results of the organic C and organic matter obtained in the dumpsites were significantly different and higher ($P<0.05$) than the corresponding adjacent open sites. The results indicate that dumpsites increased soil organic carbon content in the locations (Figures 1 and 2). The organic carbon content in the dumpsites located in Umuahia Abia State was found to be 3.71 and 2.99%, while the adjacent open sites had mean values of 1.20 and 1.05% in soil depths of 0-20 and 20-40 cm. However, in Imo State, the values of the organic carbon at 0-20 cm soil depth were higher when compared with those of Abia, and also significantly higher than that of the adjacent open sites (Tables 1 and 2). Therefore, the organic matter values followed similar trend with those of organic carbon. The results also show the influence of dumpsites on the total N and available phosphorus of soils in Imo and Abia States at 0-20 and 20-40 cm depths. Dumpsites in both locations increased the total N and available P of the soils when compared with the adjacent open sites.

Table 1: Effect of Dumpsites on Organic carbon, Total nitrogen, pH and Available Phosphorous of soils in Abia and Imo States at 0 – 20 cm Depth

		Attribute					
Location	**Treatment**	**pH (H_2O) 1:2.5**	**OC ----%--**	**OM --- % ---**	**N ----%---**	**Avail. P (mg/kg)**	**C:N**
Abia State	Umuahia	8.20	3.71	6.39	0.52	54.10	7.13
	Isuikwuato	7.10	3.12	5.38	0.48	48.55	6.50
	Um – AOS	4.90	1.20	2.07	0.24	31.00	5.00
	Isu - AOS	4.45	1.28	2.19	0.19	23.74	3.94
	F-$LSD_{0.05}$	1.62*	1.35*	2.33*	0.14*	16.48*	2.89*
Imo State	Umuna	7.60	4.19	7.22	0.60	60.30	6.98
	Okigwe	6.65	3.93	6.77	0.55	59.05	6.00
	Uma– AOS	4.70	0.94	1.62	0.17	23.10	13.42
	Ok - AOS	4.52	0.91	1.57	0.10	29.12	9.10
	F-$LSD_{0.05}$	1.34*	0.88*	1.52*	0.12*	17.82*	5.99*

OC = Organic carbon; OM = Organic matter; N = Total nitrogen; Avail. P = Available phosphorus; * = Significant at 5% probability level; Um-AOS = Umuahia Adjacent Open Site; Isu-AOS =Isuikwuato Adjacent Open Site; Uma AOS = Umuna Adjacent Open Site; Ok- AOS = Okigwe Adjacent Open Site.

Table 2: Effect of Dumpsites on Organic carbon, Total nitrogen, pH and Available Phosphorous of soils in Abia and Imo States at 20 - 40 cm Depth

		Attribute					
Location	**Treatment**	**pH (H_2O) 1:2.5**	**OC ----%----**	**OM ---- % ----**	**N ----%--**	**Avail. P (mg/kg)**	**C:N**
Abia State	Umuahia	5.50	2.99	5.15	0.30	31.00	9.97
	Isuikwuato	6.10	2.68	4.62	0.29	28.09	9.24
	Um – AOS	4.50	1.05	1.81	0.15	20.90	7.00
	Isu - AOS	3.91	0.89	1.53	0.13	16.86	6.85
	F-$LSD_{0.05}$	0.71*	0.99*	1.75*	0.11*	3.61*	0.26*
Imo State	Umuna	5.20	2.19	3.78	0.24	30.30	9.13
	Okigwe	5.84	1.98	3.41	0.26	29.03	7.62
	Uma – AOS	4.40	0.96	1.66	0.10	12.20	9.67
	Ok - AOS	4.06	0.82	1.41	0.11	15.12	7.46
	F-$LSD_{0.05}$	0.63*	0.64*	1.31*	0.00^{NS}	12.80*	0.19

OC = Organic carbon; OM = Organic matter; N = Total nitrogen; Avail. P = Available phosphorus; * = Significant at 5%probability level; Um-AOS = Umuahia Adjacent Open Site; Isu-AOS = Isuikwuato Adjacent Open Site; Uma-AOS = Umuna Adjacent Open Site; Ok- AOS = Okigwe Adjacent Open Site.

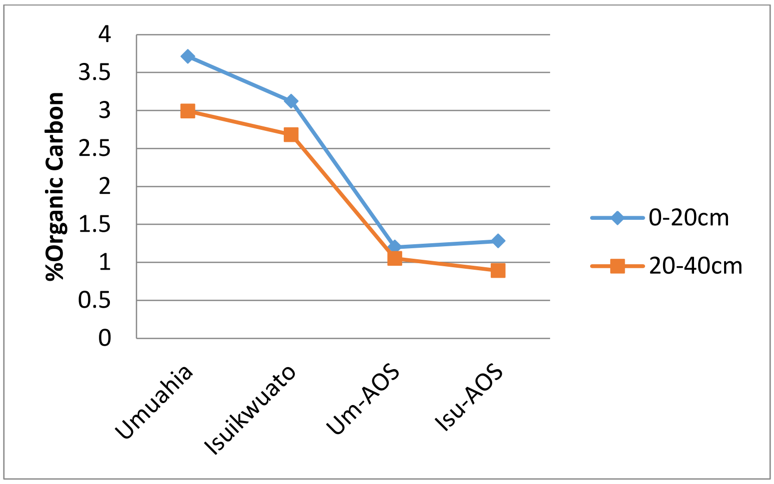

Fig. 1: Organic carbon storage in Abia State dumpsites and their adjacent sites at 0 – 20 cm and 20 – 40 cm soil depth

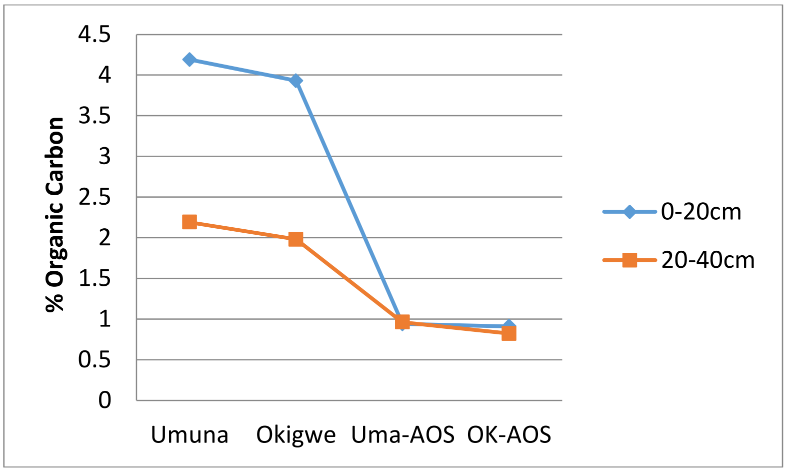

Fig. 2: Organic carbon storage in Imo State dumpsites and their adjacent sites at 0 – 20 cm and 20 – 40 cm soil depth

Tables 3 and 4 summarize the influence of municipal waste dumpsites on the exchangeable bases, effective cation exchange capacity (ECEC), exchangeable acidity and base saturation of soils in Imo and Abia States at soil depths of 0-20 and 20-40 cm. However, when compared with the adjacent open sites, the dumpsites increased the exchangeable bases (Ca++, Mg++, K+ and Na+), ECEC, percent base saturation and reduced the exchangeable acidity of the soils in the various locations. Therefore, the significant improvements in the soil chemical characteristics in dumpsite soils when compared with those of adjacent open sites were marginal and more pronounced. For example, sodium (Na+) values in Imo (Umuna) and Abia (Umuahia) dumpsites were 0.34 and 0.27cmol(+)kg-1 which were significantly higher ($P<0.05$) than their adjacent open sites with values of 0.21 and 0.07 cmol(+)kg-1 at 0-20 cm depth, respectively (Table 3). The values of Na+ obtained in Table 4 followed similar trend.

Also in Tables 3 and 4, calcium (Ca++) values in the dumpsites were moderate, whereas those of the adjacent open sites were low. Dumpsites in Imo (Umuna) and Abia (Umuahia) had Ca++ values of 9.70 and 6.80 cmol(+)kg-1 as well as 5.60 and 6.40 cmol(+)kg-1 at 0-20 and 20-40 cm soil depth, respectively. These Ca++ values were significantly higher than their adjacent open sites with values of 3.60 and 2.39 cmol(+)kg-1 as well as 1.60 and 1.20 cmol(+)kg-1 for Uma-AOS and Um-AOS, respectively.

Generally, in Tables 3 and 4, the magnesium (Mg++) values in the dumpsites were high, while the corresponding values obtained in their adjacent open sites were moderate. For example, in Imo (Umuna) and Abia (Umuahia) at 0-20 cm soil depth, dumpsites had Mg++ values of 4.4 and 4.0 cmol(+)kg-1, while their adjacent open sites had 1.60 and 1.8cmol(+)kg-1, respectively. The Mg++ values of 20-40 soil depth followed the same trend.

However, the results obtained in Tables 3 and 4 also show that potassium (K+) in both Imo (Umuna) and Abia (Umuahia) were generally low with values of 0.24 and 0.26cmol(+)kg-1, whereas their adjacent open sites were 0.13 and 0.14cmol(+)kg-1, respectively. Therefore, the K+ values in dumpsites were significantly higher ($P<0.05$) than those of their adjacent open sites.

Also, Tables 3 and 4 point to the fact that the dumpsites significantly reduced the exchangeable acidity (EA) of the soils at the various depths. The values of EA in the dumpsites were significantly lower than their corresponding adjacent open sites. The values of ECEC and percent base saturation followed similar trend with those of the exchangeable bases.

Table 3: Effect of Dumpsites on exchangeable bases, effective cation exchange capacity and base saturation of soils in Abia and Imo States at 0 – 20 cm depth

		Na^+	Ca^{++}	Mg^{++}	K^+	EA	ECEC	BS
		--------------------- cmol(+)kg^{-1}						--%---
Location	**Treatment**							
Abia State	Umuahia	0.27	6.80	4.0	0.26	0.24	11.57	97.9
	Isuikwuato	0.30	6.00	3.2	0.31	0.30	10.11	97.0
	Um – AOS	0.07	2.39	1.8	0.14	1.26	5.66	77.7
	Isu - AOS	0.10	1.98	1.2	0.16	1.18	4.64	74.1
	F-LSD$_{0.05}$	0.01*	0.57*	0.6*	0.08*	0.22*	2.90*	4.42*
Imo State	Umuna	0.34	9.70	4.4	0.24	0.54	15.22	96.5
	Okigwe	0.41	8.62	3.8	0.36	0.44	13.63	96.8
	Uma – AOS	0.21	3.60	1.6	0.13	0.96	6.50	85.2
	Ok - AOS	0.19	2.33	1.3	0.11	1.12	5.05	77.8
	F-LSD$_{0.05}$	0.032*	4.38*	2.03*	0.16^{NS}	0.05*	3.47*	5.31*

Na+ = Sodium; Ca++ = Calcium; Mg++ = Magnesium; K+ = Potassium; EA = Exchangeable acidity; ECEC = Effective cation exchange capacity; BS = Base saturation; * = Significant at 5% probability level; Um-AOS = Umuahia Adjacent Open Site; Isu-AOS = Isuikwuato Adjacent Open Site; Uma-AOS = Umuna Adjacent Open Site; Ok- AOS = Okigwe Adjacent Open Site.

Table 4: Effect of Dumpsites on exchangeable bases, effective cation exchange capacity and base saturation of soils in Abia and Imo States at 20 -40 cm depth

		Na^+	Ca^{++}	Mg^{++}	K^+	EA	ECEC	BS
		--------------------- cmol(+)kg^{-1}						--%---
Location	**Treatment**							
Abia State	Umuahia	0.22	6.40	4,80	0.24	0.88	12.54	93.0
	Isuikwuato	0.26	5.51	3.62	0.22	0.64	10.03	93.6
	Um – AOS	0.07	1.20	1.00	0.09	1.20	3.56	66.3
	Isu - AOS	0.09	2.01	1.53	0.06	1.16	4.85	76.1
	F-LSD$_{0.05}$	0.03*	0.43*	0.40*	0.06*	0.23*	2.33*	3.75*
Imo State	Umuna	0.27	5.60	3.60	0.20	0.78	10.45	92.5
	Okigwe	0.21	4.93	2.93	0.19	0.80	9.06	91.2
	Uma – AOS	0.08	1.60	0.80	0.09	1.05	3.62	71.0
	Ok - AOS	0.11	1.19	0.98	0.06	1.10	3.44	68.0
	F-LSD$_{0.05}$	0.01*	0.24*	0.05*	0.071*	0.10*	5.385*	3.08*

Na+ = Sodium; Ca++ = Calcium; Mg++ = Magnesium; K+ = Potassium; EA = Exchangeable acidity; ECEC = Effective cation exchange capacity; BS = Base saturation; * = Significant at 5% probability level; Um-AOS = Umuahia Adjacent Open Site; Isu-AOS = Isuikwuato Adjacent Open Site; Uma-AOS = Umuna Adjacent Open Site; Ok- AOS = Okigwe Adjacent Open Site.

Discussion

However, the improvement in soil chemical characteristics of soils in the dumpsites when compared with the adjacent open sites were more pronounced. The organic matter values obtained in this study were high. According to Rahman, et al.(2013), the very high values of organic matter obtained in the dumpsites may be as a result of addition of organic materials such as crop residues, animal manures, and green manures to soils. The authors added that soil organic matter undergoes mineralization and releases substantial quantities of nitrogen, phosphorus, sulfur and smaller amount of micronutrients. The high organic matter values obtained in the dumpsites in both locations might be the cause of increased total N, available P and soil pH. Anijah – Obi (2001) with similar results was of the opinion that taking all organic food serapes, including coffee ground and eggshells and throwing them in layers on a compost pile eventually breaks down and become nutrient –rich fertilizers. Anikwe and Nwobodo (2001) added that the municipal waste increases the content of soil organic matter, nitrogen, pH, cation exchange capacity and percentage base saturation. The increases in values of the elements were similar to the results of the above authors. The pH values obtained in the dumpsites were alkaline in reaction. Essien and Hanson (2013) made similar observations and opined that the high pH (alkaline in reaction) is attributed to the organic accumulated on the soils. This means that organic solid waste accumulation could significantly reduce soil acidity ($p<0.05$), and confirms the observation by Isirimah (2000) that there is increase in salinity in soils under accumulated municipal solid waste. The level of the salinity however, may depend on the composition of the solid waste.

In addition, increase in the exchangeable bases of the dumpsite soils more than their adjacent open sites could be attributed to the high organic matter values obtained in the dumpsites. Roy and Kashem (2014) with similar results confirmed that the addition of organic materials such as crop residues, animal manures, green manures to soils have a direct effect on soil organic matter content and can improve soil fertility, soil physical characteristics, augment microbial activities and ameliorate metal toxicity. Read (1996) also made similar observations.

Conclusions

The results obtained from the study points to the fact that dumpsites in both Imo and Abia increased the chemical properties of the soils, and there were significant differences (P<0.05) between the values of the dumpsites and the adjacent open sites. In view of the results obtained in this study and high level of nutrient elements in the dumpsites, I strongly recommend that dumpsite soils be used for crop production as there may not be any need for additional fertilizer application. Following the onset of industrialization and the sustained urban growth of large population centers in Imo and Abia states, the buildup of waste in the cities caused a rapid deterioration in levels of sanitation and the general quality of urban life. The streets became choked with filth due to the lack of waste clearance regulations. Calls for the establishment of a municipal authority with waste removal powers occurred some years back. As the preservation of the health of the people is of great importance, it is proposed that the cleaning of this city should be put under one uniform public management, and all the filth be conveyed by the Agencies to proper distance in the state where farmers could come to carry them to their farms.

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