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A PRELIMINARY ASSESSMENT OF THE IMPACT OF SOLID WASTES ON SOILS AND GROUNDWATER SYSTEM IN PARTS OF PORT HARCOURT CITY AND ITS ENVIRONS, RIVERS STATE, NIGERIA.

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ABSTRACT

Soil and groundwater samples from four refuse dumpsite locations in Port Harcourt city and its environs were studied to assess the impact of solid wastes on soils and groundwater system in the area. The study shows significant abundances of Cu, Pb, Zn in soils, in the following ranges Cu: 0.0055-2.31%, Pb: 0.002-3.08%, and Zn 0.001-1.93%. This shows that the soils are contaminated to hazardous levels when compared with acceptable standards. The concentrations of these metals are found to decrease with depth in the soils. However, groundwater in the area is potable and not polluted by the chemical species studied (pH, Fe, Zn, Cd, Cu, Pb, Mn, Cl and NO_3). It also shows low levels of BOD, COD, TDS, Hardness and coliforms.

The metal enrichments in the soils owe their origin to the refuse dumps as well as other sources like dissolution from parent rocks, buried oil pipes and fuel reservoirs, geochemical processes operating within the groundwater system, and atmospheric precipitation. The tolerable concentrations of the parameters in groundwater can be explained by the geologic control on the movement of chemical species in the soils.

KEY WORDS: Solid waste, impact, soil, groundwater, Port Harcourt.

INTRODUCTION

Port Harcourt city and neighbouring Local Government areas have experienced significant industrial development and population growth since the creation of Rivers State in 1967 to its becoming the administrative headquarters of the state and due to oil exploration and exploitation activities and other downstream industries. As a result of these activities and the resultant increase in population, domestic and industrial wastes are generated on a daily basis. The volume of these refuse collected yearly in Port Harcourt between 1987 and 1993 is shown Table 1 and Fig. 1. The wastes are composed mainly of garbage, rubbish, dead animals and trash. Other components include chemicals, paints, sands, explosives, etc. Due to the absence of close monitoring of waste disposal in the study area, these wastes are commonly dumped along roadsides, at market places, and in other unapproved refuse dumpsites. Even those disposed at approved open dumpsites are not properly managed. The impact of these carelessly dumped/managed wastes is enormous on all aspects of environment-soil, water and air. For example, leachates from the wastes can infiltrate with precipitation into the groundwater system, polluting it and causing health problems of epidemic dimension to consumers.

The present study aims at evaluating the effect of municipal solid wastes of various refuse dumps on soils and groundwater system in Port Harcourt city and its adjoining areas. This became necessary as the inhabitants of these areas depend mostly on groundwater for their water supply needs.

The study area is located in the Rivers State, within Niger Delta Sedimentary Basin of Nigeria. The area lies between latitudes 4°30'and 5°00'N and longitudes 6°45' and 7°30'E (Fig. 2), and is situated within the subequatorial region. This region is characterized by alternate wet and dry seasons (Iloeje 1972). The rainy season starts in March and ends in October, with a peak in June and July. The rains are ushered in by the south west rain bearing winds which blow from the Atlantic Ocean into Nigeria. Within the rainy season, there is a short period of little or no rain styled the 'August Break' which is commonly experienced in the month of August. The dry season begins in November and lasts till March, with a short harmattan in December and early January. It is brought by the dry northeastern winds which blow across the Sahara desert into Nigeria. The total annual rainfall in the area as measured by the Meteorological Department of the Federal Ministry of Aviation in Port Harcourt between 1970 and 1990 ranges between 1632mm and 2567mm. Relative humidity values are generally over 80%, and the mean annual temperature is about 28°C in the area.

GEOLOGY AND HYDROGEOLOGY

The Niger Delta Sedimentary Basin extends across the study area. Generally, the Delta is characterized by three formations, namely Akata, Agbada and Benin. These formations consist primary of regressive Tertiary age sediments. The detailed geology of the Niger Delta formations is given by Reyment (1965), and Short and Stauble (1967). The basal Akata Formation consists of low density, high pressure, shallow marine to deep water shales (Schield, 1978). The Agbada Formation consists of alternating deltaic (fluvial, coastal, fluviomarine) sands and shale. The Benin Formation consists of freshwater continental (fluviatile) sands and gravels, with occasional clay layers, and an overall thickness of 0-2130m (Schield, 1978). It is Miocene to Recent in age and constitutes the major aquiferous layer in the study area.

The thin clay units in the Benin Formation have resulted to a multi-aquifer system in the study area as it is the case in most parts of the Niger Delta where this formation outcrops (Etu-Efeotor, 1981; Edet, 1993; Udom et al; 1997, 1998). Etu-Efeotor (1981) identified two major aquifers in Rivers State from strata logs. The upper one (where all the environmental boreholes drilled during this study tap from) is more prolific and extends to about 80 metres, while the underlying one is less prolific. Information gathered from Rivers State Water Board, and other available borehole records from other water agencies, show that borehole depths in the state commonly range from 35 to 90 metres; Static Water Level (SWL), 1-20 metres; transmissivity, 500-10,000m^2/d; and hydraulic conductivity, 5 – 60m/d.

STUDY TECHNIQUES

The chemistry of soil, leachates and groundwater samples collected from the dumpsites and their neigbourhood were studied. Particle size distribution of the soil samples were also studied by dry sieving to estimate the permeability of the soil using Hazen's (1982) formula as follows:

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Table 1: Monthly refuse collection data for Port Harcourt and environs in metric tons.

	YEAR/VOLUME						
Month	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**
January	10,475	15,520	12,752	17,401	7,722	5,032.5	15,300
February	11,535	16,504	14,288	15,375.5	5,508	4,323	-
March	13,318	14,976	14,893	17,210.5	4,075	4,212	23,790
April	11,665	11,692	15,842	16,259.5	3,118.5	16,491.5	14,343
May	12,600	15,504	15,857	17,660	3,575.5	25,513.5	12,755.5
June	12,880	14,136	16,700	17,689	3,481.5	70,897.0	15,632.5
July	8,250	14,744	16,351	16,759	5,458.5	3,399	13,498
August	7,750	15,744	14,553	14,447.5	4,768.5	3,679.5	12,953.5
September	7,750	15,744	14,557	1,447.5	5,903.5	3,366	13,976.5
October	10,770	12,464	14,322	1,419	5,692.5	3,102	15,857
November	11,760	17,008	17,648	16,058.5	5,478	3,696	14,893
December	14,224	15,056	16,187	14,108.5	4,855	4,148	14,947
TOTAL	**132,977**	**179,092**	**183,950**	**165,835.5**	**59,636.5**	**147,860**	**167,946**

(Source: Environmental Protection Agency Port Harcourt).

$$K = Cd_{10}^2,$$

where K = hydraulic conductivity, cm/s
C = constant (for K in cm/s and d_{10} in mm, C = 1
d_{10} = effective diameter, mm defined as diameter such that 10% by weight of the porous matrix consists of grain smaller than it.

The d_{10} components (Table 2) used in this formula were obtained from particle size distribution curves at Nkpolu and Elekahia. A typical example of these plots for BH1 (10m) in Nkpolu is shown in Fig. 3. Some of the soil samples were obtained from the six environmental boreholes drilled during the study at Nkpolu and Elekahia dumpsites, while the rest were collected by auger boring from Rumuopirikom and Eastern by-pass dumpsites (Table 3). A control soil sample was collected from the Abuja Park of the University of Port Harcourt (Uniport) located in Obio-Akpor L.G.A. Water samples were also obtained from the drilled boreholes and boreholes in adjoining areas to Rumuopirikom and the Eastern by-pass dumpsites. The control water sample was also obtained from a borehole in Abuja Park, Uniport. The soil samples were collected at 1 meter depth intervals.

Soil pH was determined by electrometric method (Bates, 1954). Standard solutions of the soil samples were made according to Jackson (1951) and Black (1965) to determine the concentration of Zn, Cd, Cu, Mn, and Cl using atomic absorption spectrophotometer (AAS). The water samples and the leachates were analysed for Fe, Zn, Cd, Cu, Pb, Mn, using the AAS also. The concentrations of the heavy metals were extrapolated from standard curves due to Vogel (1962). pH was measured with a pH meter; while SO_4, NO_3 and TDS were got by gravimetric methods. Cl and hardness were titrated for; whereas BOD and COD were determined according to the American Public Health Association (1989) standard methods.

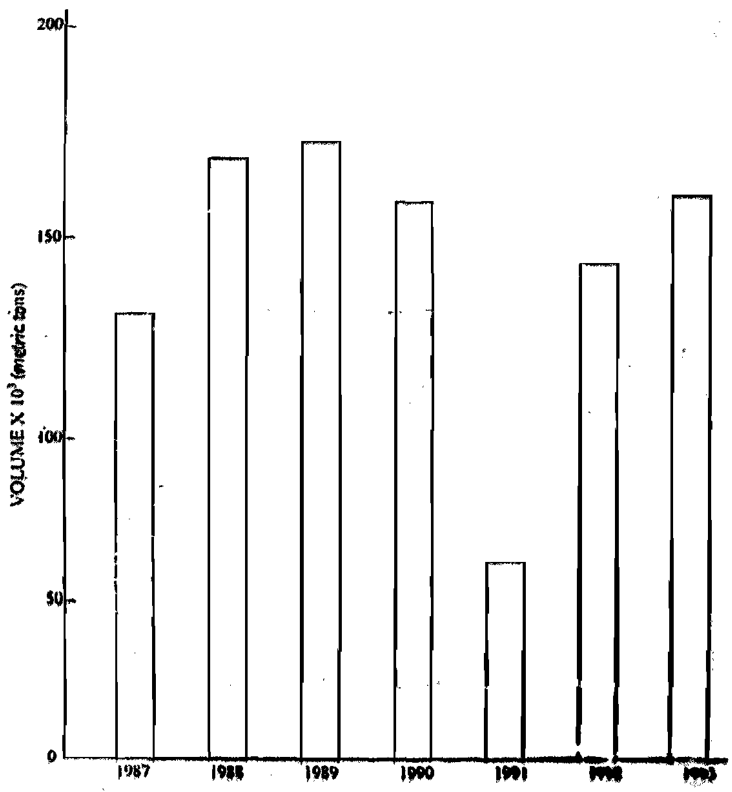

Fig. 1: Total refuse collection for Port Harcourt and environs between 1987 and 1993 (Source: Environmental Protection Agency, Port Harcourt).

Fig. 2: Map of Port Harcourt/Obio Akpor L.G.A.s showing dump locations/sampling points.

Table: Summary of Sieve analysis results/hydraulic conductivity values of soil samples from two of the six boreholes drilled during the study.

Borehole Number	Borehole Location	Sample Depth (m)	% Passing Sieve Size Number					D10 (mm)	K x 10-2 cm/s
			2 mm	1 mm	0.425 mm	0.150 mm	0.075 mm		
BH1	Nkpolu	0	100	97.1	47	7.5	2.4	0.155	2.4
		1	99.4	95.4	30.8	3.8	1.1	0.200	4.0
	N04°52.187'	5	99	96.1	40.3	7.3	2.1	0.156	2.4
		10	100	96.3	50.3	3.6	2.1	0.190	3.6
	E006°58.344'	13	99	86.4	30.3	0.9	0.2	0.220	4.8
BH4	Elekahia	0	97.8	75.3	36.4	5.8	1.9	0.210	4.4
		1	98.0	74.6	33.2	4.8	2.3	0.270	7.3
	NO4°.49.149'	5	99.4	81.6	40.8	8.2	1.4	0.230	5.3
		10	86.4	60.7	39.1	7.8	0.9	0.210	4.4
	E007.01.801'	15	78.1	62.6	27.1	2.8	0.2	0.300	9.0

RESULTS OF DISCUSSION

Average concentrations of heavy metals and pH in soils from the study area are presented in Table 4 and Fig. 4, while Table 5 contains the average concentrations of pH, Cl, SO_4, BOD, COD and heavy metals in leachates from the dumpsites. Table 6 and Fig. 5 show the average concentrations of pH, Cl, NO_3, Hardness, TDS, BOD, COD, Coliform count and heavy metals in groundwater samples in the area.

As shown in Table 4, pH values in the soils between the depth brackets of 0-2m studied range between 6.3 and 6.9. They do not show any pattern with depth, but indicate mildly acidic soils in the study area. Aerobic decomposition of organic

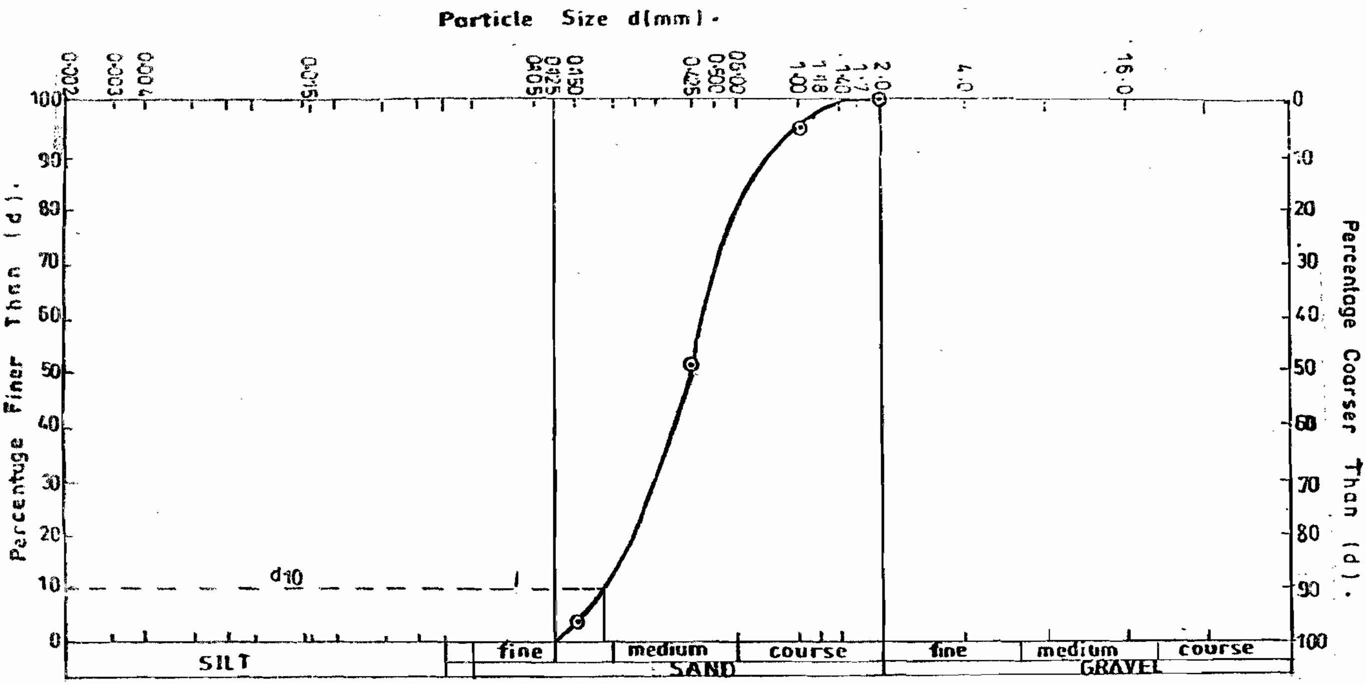

Fig-3: A typical grain size distribution plot for BHI (10) in Nkpolu.

Table 5: Data for the six environmental boreholes drilled at Nkpolu and Elekahia dumpsites

Borehole Number	Location	Depth (m)	Elevation (a.m.s.l)(m)	SWL (m)
BH1	Nkpolu N04°52.187' E006°58.344'	13	46	11
BH2	Nkpolu N04°52.211' E006°58.249'	14	47	11.2
BH3	Nkpolu N04°52.174' E00658.261'	13	35	11
BH4	Elekahia N04°.49.149' E007.01.801'	15	-	10
BH5	Elekahia N04°.49.150' E007.01.786'	15	-	10
BH6	Elekahia N04°.49.181' E007.01.778'	15	-	10.1

matter in the refuse results in the production of carbon dioxide. This gas reacts with water according to the equation below:

$$CO_2 + H_2O \longrightarrow H_2CO_3 \quad \text{.......... eqn. 1.}$$

to form carbonic acid (Holderness and Lambert, 1979) which enters the soil through leachates at the dumpsites to reduce the soil pH and cause acidity.

The soils at the dumpsites and the control (SN, SEL, SR, SEB and SC)also show appreciable heavy metal concentrations in the following ranges: Zn (0.001 – 1.93%), Fe (1.01 – 4.53%), Cu (0.0055 – 2.31%), Mn (0.021 – 2.35%), and Pb (0.002-3.08%) – Table 4 and Fig. 4. The concentrations of Zn, Cu and Pb in the soils at the dumpsites all through the 0-2m depth are higher than the average metal contents in soils by Bowen (1979) – Table 4. By comparison with Kabata – Pendias and Pendias (1984) – Table 4, these elements occur in toxic amounts in the soils at the dumpsites, except at the control. This indicates that at the dumpsites the soils are contaminated to hazardous level. Studies by Alloway (1990) shows that soils contaminated by Cu, Pb, and Zn are not suitable for food crop production.

The concentration levels of these parameters generally decrease with depth (Table 4 and Fig. 4). Also at the dumpsites (SN, SEL, SR, and SEB) the parameters show higher concentrations in the soils than at the control site (SC) located about 5km from Nkpolu dumpsite (SN). This is an indication that these parameters are discharged from the refuse into the soils through leachates. Since the heavy metal concentrations at the control site stay below Kabata Pendias and Pendias (1984) critical values (Table 4), indicating that the soil there is not contaminated, it is certain that the dumpsites are the main sources of heavy metals in the soils in the area under study. However, the existence of these metals in low levels at the control shows that these elements also owe their origin from other sources. For example, Fe and Pb can dissolve from buried oil pipes and fuel reservoirs in filling stations in the area into the soils. Fe is also a major element in the Benin Formation, which forms the top sequence in the study area. Pb may also dissolve from car batteries carelessly dumped in the area, while Cu could come from sewage.

Since the soil is permeable in the study area, with permeability values from 2.40 x 10^{-2}cm/s at Nkpolu to 9.0 x 10^{-2}cm/s at Elekahia (Table 2), these elements are bound to infiltrate deeper and deeper in the soil with time.

The leachates from the dumpsites (LN, LEL, LR and LEB) also show high values for the following parameters: Fe (2.2 – 3.6mg/1), Zn (2.8-4.5mg/1). Cd(0.09-0.1mg/l), Cu (0.98-1.67mg/l), Pb(0.98-13mg/l), Mn (0.55-0.82mg/l). Cl(1100-1986mg/l), SO_4(231-587mg/l), BOD (530-1528mg/l), and COD (1500-2063mg/l). pH values lie between 6.3 and 8.3 (Table 5). These parameters, which owe their origin to the refuse dumps, infiltrate through the soils thereby polluting them.

Borehole water samples were also analysed from the

Table [illegible]: Average Chemical Parameters in Soil Samples for various depths in study area.

Parameters	Soil Samples (%)																Acceptable standards	
	SN (n=3)			SEL (n=3)			SR (n=3)			SEB (n=4)			SC (n=4)			Value Range	xBowen	xxCritical Value
	0m	1m	2m	0m	1m	2m	0m	1m	2m	0m	1m	2m	0m	1m	2m			
PH	6.9	6.5	6.3	6.3	6.8	6.8	6.9	6.7	6.6	6.5	6.6	6.6	6.5	6.6	6.5	6.3-6.9	-	-
Zn	0.85	0.77	0.51	1.71	1.56	1.33	0.92	0.91	0.85	1.93	1.17	1.17	0.013	0.009	0.001	0.001-1.93	0.005	0.04
Fe	2.85	2.02	1.99	4.03	3.01	1.9	3.85	2.98	1.09	4.53	3.08	1.03	2.03	1.01	1.01	1.01-4.53	3.8	-
Cu	1.05	1.01	1.01	2.10	2.10	1.91	1.92	0.91	0.88	2.31	2.28	2.05	0.006	0.006	0.0055	0.0055-2.31	0.002	0.013
Mn	1.03	1.00	0.98	2.08	1.99	0.93	1.03	0.98	0.77	2.35	1.13	0.93	0.03	0.021	0.021	0.021-2.35	0.008	0.3
Pb	2.08	2.03	1.98	3.08	2.55	0.98	1.9	0.82	1.80	2.08	1.90	1.88	0.003	0.003	0.002	0.002-3.08	0.001	0.004

SN = Soil, Nkpolu; SEL = Soil, Elekahia; SR = Soil, Rumuokpirikom; SEB = Soil, Eastern By-pass; SC = Soil Control
X = Bowen (1979); xx = Kabata – Pendias and Pendias (1985); n = number of samples per parameter.

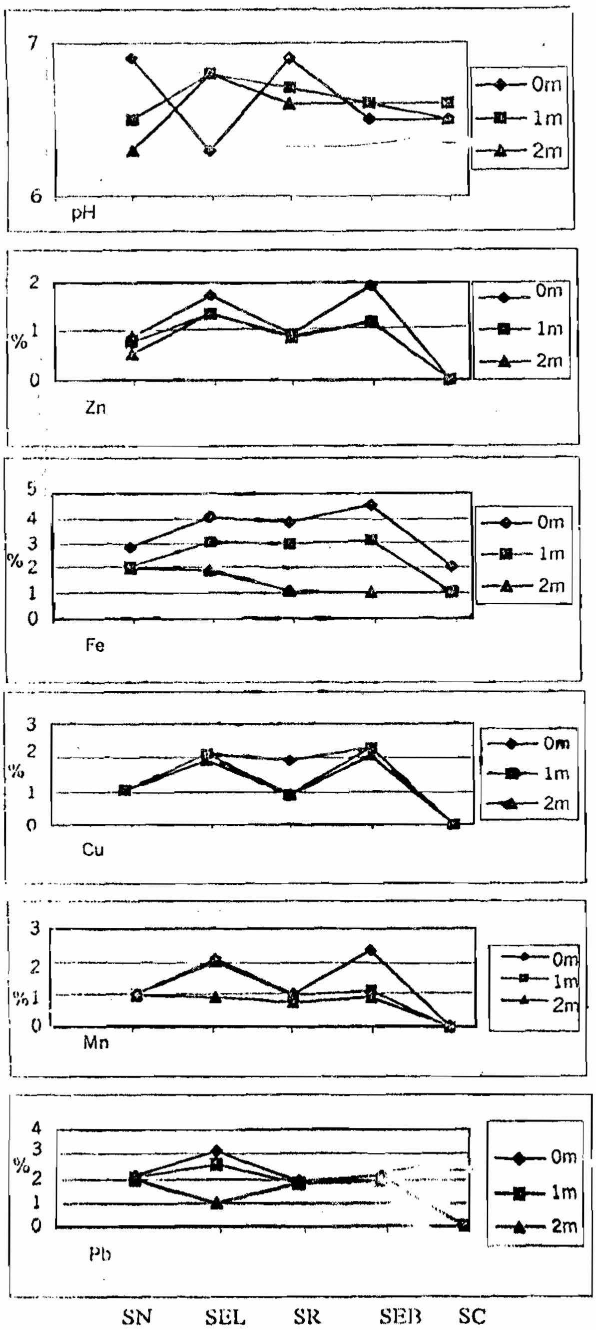

Fig. 4: Distribution patterns of pH and elements in soils within study area.

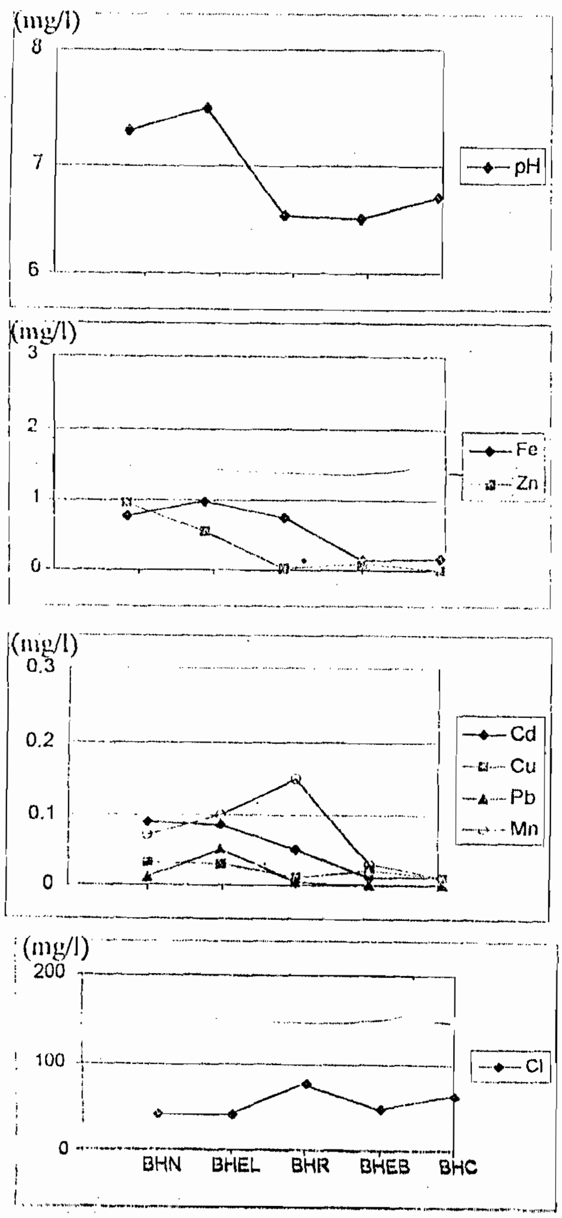

Fig. 5: Concentration of elements in groundwater samples within study area

Table 5: Average Chemical Composition Of Leachates From Dumpsites

Parameter	Leachates (mg/l, except pH)				
	LN (n=2)	LEL (n=3)	LR (n=2)	LEB (n=2)	Value range (mg/l, except pH)
pH	6.3	8.3	7.5	8.0	6.3 – 8.3
Fe	2.3	3.6	2.8	2.2	2.2 – 3.6
Zn	3.2	4.5	2.8	3.3	2.8 – 4.5
Cd	0.1	0.1	0.09	0.1	0.09 – 0.1
Cu	1.8	1.67	0.98	1.02	0.98 – 1.67
Pb	1.3	0.98	0.99	0.10	0.98 – 1.3
Mn	0.61	0.82	0.67	0.55	0.55 – 0.82
Cl	1,894	1,986	1,920	1,100	1,10 – 1,986
SO_4	587	300	231	360	231 – 587
BOD	1,528	1,200	530	987	530 – 1,528
COD	2,063	1,800	1,500	1,780	1,500 – 2,063

(LN = Leachate, Nkpolu; LEL = Leachate. Elekahia; LR = Leachate, Rumuokpirikom;
(LEB = Leachate, Eastern By-Pass; n = number of samples.

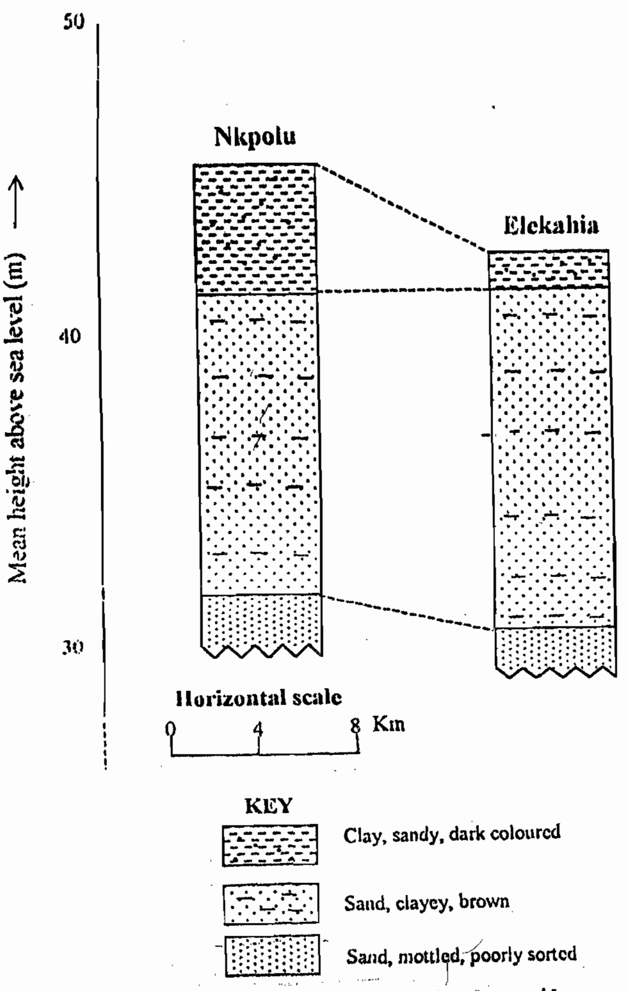

Fig. 6 Lithologic logs of some boreholes in the study area.

environmental boreholes drilled at Nkpolu and Elekahia dumpsites (BHN and BHEL). Private boreholes in Rumuokpirikom, Eastern By-Pass and the University of Port Harcourt (BHR, BHEB and BHC) were analysed for pH, Fe, Zn, Cd, Cu, Pb, Mn, Cl, NO_3, Hardness, TDS, BOD, COD and total coliform counts (Table 4). The University of Port Harcourt borehole (BHC) was the control borehole. These parameters show ranges as follows in the groundwater: pH, 6.50-7.50; Fe, 0.13-0.98 mg/l; Zn, 0.001 – 0.97mg/l; Pb, 0.001 – 0.050mg/l; Mn, 0.01 – 0.15mg/l; and Cl, 40.15-75.70mg/l (Table 6 and Fig. 5). Others include NO3, 2.30 – 5.20mg/l; hardness, 2.5-4.8mg/l; TDS, 82.3 – 100.1 mg/l; BOD, 2.23 – 3.81 mg/l; COD, 0.82-1.93 mg/l and total coliform count 0 – 1 mg/l (Table 6). Comparison with the World Health Organisation (WHO, 1984) and American Society of Civil Engineers (1969) Standards (Table 6) shows that the water is potable as all the parameters stay within acceptable limits. The water is also soft when compared with Durfor and Becker (1964) standard. The water is also not depleted in oxygen in view of the low levels of BOD and COD. This shows very low levels of microorganisms in the water. Groundwater in the area is therefore suitable for dinking and other domestic purposes. The parameters owe their origin mainly from the parent rocks from which the soils in the area were derived, geochemical processes operating within the groundwater system, atmospheric precipitation, and probably a little contribution from the leachates.

CONCLUSION

The soils at Nkpolu, Elekahia, Rumuokpirikom, and the Eastern By-Pass dumpsites in Port Harcourt and its environs show concentration levels above acceptable limits for normal soils for Zn, Fe, Cu, Mn and Pb (Bowen, 1979). Also their limits are above Kabata-Pendias and Pendias (1985) critical values showing that the soils at the dumpsites are contaminated to harzodous level, hence unsuitable for food production (Alloway, 1990).

Soils in the neighbourhood of the dumps are also likely to be affected due to dispersion of the elements. At the control site, about 5km away in the University of Port Harcourt where there is little or no dumping, the concentration levels of these heavy metals show that the soil is not contaminated. This shows that the metals are leached from the refuse into the soils at the dumpsites. The levels of these metals at the dumpsites were found to decrease with depth, but even at the maximum depth of 2m studied, the values were still higher than those of areas outside the dumpsites soils (Table 4).

Table 6: Average Chemical Concentration in Borehole water samples from the study area

Parameter	Leachates (mg/l, except pH)						
	BHN (n=3)	BHEL (n=3)	BHR (n=2)	BHEB (n=3)	BHC (n=3)	Value range	*WHO (mg/l, except pH)
pH	7.30	7.50	6.53	6.50	6.70	6.50-7.50	6.5-9.2
Fe	0.78	0.98	0.75	0.13	0.15	0.13-0.98	1.0
Zn	0.97	0.56	0.03	0.09	0.001	0.001-0.97	15
Cd	0.09	0.085	0.050	0.01	0.01	0.01-0.085	ns
Cu	0.031	0.030	0.10	0.02	0.01	0.01-0.31	1.5
Pb	0.010	0.050	0.005	0.001	0.001	0.001-0.050	ns
Mn	0.07	0.10	0.15	0.03	0.01	0.01-0.15	0.5
Cl	40.15	40.70	75.70	47.8	62.5	47.8-475.70	600
NO_3	5.20	4.80	4.83	5.03	2.30	2.30-5.20	ns
Hardness	4.8	2.5	3.2	4.5	3.6	2.5-4.8	500
TDS	98.5	100.1	85.6	100.5	82.3	82.3-100.1	1,000
BOD	3.5	3.81	2.86	3.08	2.23	2.23-3.81	**
COD	1.38	1.63	1.93	1.22	0.82	0.82-1.93	ns
Coliform count	1	1	0	1	0	0-1	-

BHN = Borehole, Nkpolu; BHEL =Borehole, Elekahia; BHR = Borehole, Rumuokpirikom; BHEB = Borehole, Eastern By-Pass; BHC = Borehole Control (University of Port Harcourt); n = number of samples;
*WHO (1984) = maximum permissible limits; ns = not stated, ** 1 – 3 excellent source: 3 – 4 good sources; 4 – 6 poor sources; > 6 rejectable (American society of civil engineers, (1969).

The leachates studied also show high concentration levels for the following parameters: Fe, Zn, Cd, Cu, Pb, Mn, Cl, SO_4, BOD and COD. This further confirms that the parameters owe their origin to the dumps. However, other sources may also account for the origin of the parameters in the soil. These include dissolution from parent rocks, buried oil pipes and fuel reservoirs, Pb-acid batteries; and others.

Groundwater samples collected from environmental boreholes drilled at Nkpolu and Elekahia dumpsites and other boreholes in the neighbourhood of Rumuokpirikom and Eastern By-Pass dumpsites show quality status within acceptable limits of WHO (1984) – Table 6. Thus, groundwater in the area is potable. It was also observed that the quality status of the water around and within the dumpsites is not significantly different from that of the control located about 5km away from Nkpolu dumpsite in the University of Port Harcourt. This is also an indication that the groundwater system in the area has not been polluted by leachates from the dumps. The tolerable concentration of the parameters studied in the groundwater (Fe, Zn, Cd, Cu, Pb, Mn, NO_3, hardness, TDS, BOD, COD and total coliform count) can be explained by the geologic control on the movement of chemical species in the soils. The lithologic sequence comprises mainly of sandy clays (Fig. 6). This lithology is likely to delay the movement of the parameters through the soils by adsorption. As a result, the contribution of these parameters by leachates from the dumpsites stops at infiltration level without significant percolation. However, since the ground is permeable, and the static water level (SWL) moderately low (10m at Elekahia to 11.2m at Nkpolu, Table 3), steps should be taken to arrest further infiltration of the leachates through the ground because over a long time the metals and other parameters from the leachates can show up in the groundwater system. The best way of handling this problem is to evacuate the refuse, rehabilitate the dumpsites, and construct a sanitary landfill in Port Harcourt. At this landfill, refuse would be properly handled without polluting the soil and groundwater system in the area.

It is also suggested that boreholes should tap water from deeper depths than the average depth of about 30m common in the area. The boreholes should be properly constructed to grout off areas of possible poor water quality. Government owned water agencies should be made to regulate monitor groundwater quality in Port Harcourt and its environs where dumping of solid wastes is common.

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