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Studies on the Inorganic Chemicals and Microbial Contaminants of Health Importance in Groundwater Resources in Port Harcourt Rivers State Nigeria

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Abstract: Eight stations of the waste collection sites in Port Harcourt city were sampled for a period of one year to determine the level of inorganic chemicals and microbial contaminants in the environment. Temperature ranged from 24.5 to 28°C while pH values recorded between 3.3 to 7.3. Organic matter content recorded 2.03%, which was found to be conducive for chelate formation as well as exchange infiltration of surface water to cause flooding. The mean textural class for the soils was predominantly sandy loam. The values for the metal concentrations in the soils revealed that they were above recommended permissible limits in all the stations high enough to cause severe pollution to the environment. Thus, the presence of pathogenic microorganisms especially the fecal coliforms and fungi species in the boreholes from the various stations is a major concern for consumers because of their effect on the health of the populace. Adequate treatment of waste is required before discharge into the environment.

Key words: Port Harcourt city, inorganic chemicals, microorganisms, groundwater, soils, boreholes

INTRODUCTION

Port Harcourt city was one of the neatest cities in Nigeria due to the absence of open ground storage of refuse and presence of aesthetic vegetation around the city. But presently the indiscriminate dumping of refuse (industrial, commercial and household) by roadsides and gutters is a very common practice. In the early 1980s, the collection system for municipal refuse in the city employed the use of roll-off containers. This involves the placement of steel containers strategically throughout the city, to which residents must deliver refuse (Isirimah, 2002). This system reduced illegal refuse dumping and does not pollute the soil and ultimately groundwater. Presently refuse are stored on the ground at residential areas, commercial sites and street corners. Government authorizes some of these storage grounds as collection points while most are illegal acquired by members of the public.

However, the quality of groundwater is a function of natural processes as well as anthropogenic activities (Sajjad *et al*., 1998). It has also been unequivocally demonstrated that water of good quality is crucial to sustainable socio-economic development (Krantz and Kifferstein, 2005). Contamination of drinking water supplies is a result of various types of industrial processes and disposal practices. As the population of Port Harcourt city continues to rise, human activities including soil fertility remediation, indiscriminate refuse and waste disposal and the use of septic tanks, soak away pits and pit latrines are on the increase. These activities are capable of producing leachates into the groundwater formation that serve as source of water to the inhabitants of the city.

However, the quality of water may be described in terms of the concentration and state (dissolved or particulate) of some or all of the inorganic and organic material present in the water together with certain physical characteristics of the water (NSWQC, 1994). The physicochemical properties also cause the development of colours, bad odour and eutrophication and reduction of sunlight through water, consequently affecting aesthetic quality of water. The heavy and trace metal present in polluted water enter into human body through food chain and may cause adverse effects (Stein *et al*., 1990; Erah *et al*., 2002). Also, the consumption of bacterial infected water and water contaminated by some metals has dare consequences on the health of the

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consumers. For example in 1989, tens of millions of people were believed to be drinking arsenic- rich water in West Bengal, India and Bangladesh with as many as 200,000 people in West Bengal estimated to have been poisoned (Jacobson, 1998). The incidence of groundwater contamination by high levels of inorganic chemicals in the groundwater also been reported in Benin City, Nigeria (Erah *et al*., 2002).

The main purpose of this study therefore is to investigate whether the levels of inorganic chemicals and microbial contaminants from the various collection sites for solid waste disposal in Port Harcourt city are sufficient enough to affect the quality of the ground water resources as well as the health of the inhabitants of the city.

MATERIALS AND METHODS

Sample area: Information on refuse collection points in Port Harcourt city were obtained from the Rivers State Environmental Sanitation Authority (RSESA). According to RSESA (2005), Port Harcourt city and its environs are divided into 14 zones (Table 1) for the purpose of refuse evacuation. In this study only 8 zones were randomly selected as sample collection points based on the following criteria:

- The collection point should have been in use for at least 10 years;
- There should be a few water boreholes which have also been in use for at least 10 years within the proximity of the collection point
- The water boreholes where water samples would be collected from should be located South-East of a collection point under investigation (this is because the direction of groundwater flow in Port Harcourt is North-East(Rivers State Water Board,1990).
- Study sites are located in areas where other sources of contamination to ground water are negligible.

The location sites are as follows:

- Mile 1 Market, Diobu
- Elechi Street, Mile 3
- Club Road
- Harold Wilson Drive, Borikiri
- Garri Market, Moore house Street
- New layout Market
- Behind Ibru Fishes, D/Line
- Aggrey Road by Police Children's School.

Sample collection: The water samples from the 8 collection points in the city were obtained from boreholes for water quality assessment. The sites for sample collection were within the Port Harcourt city. Each site was visited once a week and triplicate samples were collected from various parts of the system from the points during one-year period from November 2004 to November 2005. Samples were collected in screw-capped bottles and placed in a cooler for transportation. Once samples were collected they were immediately taken to the IPS Laboratory, RSUST Port Harcourt, Nigeria for analysis.

For the soil samples with the use of a spade and hand auger, 2 g soil samples were taken from depths of 0-15 cm and 105-120 cm in polyethylene bags within the perimeter of each refuse collection point (Isirimah, 2002) . For the control, soil samples were collected from an area remote at least 25 m away and upslope from each refuse collection point (Baker *et al*., 2004).

Determination of physico-chemical parameters: Average value of three replicates was taken for each determination. Temperature, pH were taken immediately after collection of both water and soil samples. Phosphorous and organic carbon contents were determined by titration methods approved by UNEP/WHO (1987) and APHA (1998). Also particles size of each soil sample was analyzed to study the movement of these organics through the soil profile.

Determination of concentrations of metals: The levels of various metals in soil samples collected from 0-15 cm and 105-120 cm depths were analyzed. The concentration of Zinc (Zn), Lead (Pb), Chromium (Cr) and Cadmium were determined using the method of Udo (1986). Two grams of air-dried soil sieved with 2 mm mesh were then weighed into 150 mL beaker. To this were added 20 mL of concentrated $HN0_3$ and 15 mL HCl_{04} after the solution has been allowed to stand for 1 h. The mixture was then digested on a hot plate until it turned to white. The residue was dissolved in dilute HCl and filtered.

Percentage absorbance and transmittance were determined by using an Atomic Absorption Spectrophotometer (Analyst 300, Perkin Elmer) (Hussein *et al*., 2004) at a wavelength of 660 nm. In determining the quality of groundwater, World Health Organization permissible limits (Guidelines for Drinking Water, 1998) were applied.

Microbiological analysis: The presence of various species of bacteria and fungi in the soil and water samples collected from the zones were evaluated using standard procedures (APHA, 1998; Cheesbrough, 1991; Hutton, 1983; Paul and Clark, 1988).

Briefly, each water sample was vigorously shaken and 0.1 mL aseptically withdrawn and spread on each previously prepared Nutrient agar (NA), Blood Agar (BA)

Table 1: Refuse collection points in port harcourt and environs

Zone	Area covered	No. of collection points	Company (contractors)
1	Borikiri including all water fronts, Old Port Harcourt township including I.B. Johnson, Bundu and Club Road to Marine base.	33	Lomo Nig Ltd
2	Harbor road to Reclamation; Station road to Superbod; NPA, Secretariat complex, Azikiwe road up to flyover, Sangana area, Abonema wharf road up to Njemanze street; Abali park to Kaduna street junction on Aba road, Abakiliki street up to Nsuka street.	32	Polsen Nig Ltd
3	Mile 1; Education bus stop up to Ikoku junction, Okija street up to Post primary schools board, UST campus Iloabuchi road and all adjoining streets.	36	DEEN Nig Ltd
4	Ikoku junction to Azikiwe street through Ojoto junction to Mile 3 park. Ikoku junction up to police barracks, Building materials up to UST R/A, AGIP R/A to Eagle Island.	32	RTK Nig Ltd
5	Agip junction up to Wimpy Junction Rumuolumeni and environs, Mgbosimini, Ebara road and adjoining streets up to Rumuokuta junction through NTA road to Choba East – west road junction	19	Palsco Ng Ltd
6	Rumuola Village, CAS, Psychiatric hospital road, Eligbam, Orazi, Obi wali road Rumuigbo down to hospital junction Rumuokwuta and environs	25	Fugodes Nig Ltd
7	Choba, Uniport, Alekahia,East-West road ,Rumuokoro up to FGC (PH) Rumuodamaya, Igwuruta up to Omagwa Airport	19	Maufil Nig Ltd
8	Rumuodara, Eneka, Atali, Rumukwurushi village up to Oil mill junction.	28	Glorious Co Nig Ltd
9	Elelenwo, Akpajo, Oyigbo town, Iriebe and Umuebulu 1 and 2.	21	Industrial Support Nig Ltd
10	Rumukwurushi to Artillery 1 and 2, Rumuogba Estate up to Air force base, Bori camp down to Rumuola (under Flyover) down to waterlines junction on Aba Road	16	Panumu Nig Ltd
11	Rumuibekwe Estate and village, Woji 1 and 2, Rumubiakani R/A to Oginigba up to Azuabie	23	Richo Nig Ltd
12	GRA 1,2and3 Presidential Estate 1, 2 and 3 D/line area including Olu-Obasanjo (from Citizens bank to water lines junction) and Oroworukwo village-Aba road (Kaduna street junction to Garrison left side)	15	Socrates Nig Ltd
13	Rumuomasi down to Rumuobiakani R/A, from Rumuomasi junction (Aba road) to Elekahia including Stadium road through Christian Council to Nkpogu junction to Kalagbor	24	Akor and Fedelis
14	Old GRA area including Amadi flats, Eastern –by-pass to Garrison, Nkpogu junction to Trans Amadi road up to Zoo R/A – Aba road (Kaduna junction to garrison right side)	17	REFCOL

Source: RSESA, 2005

and Saboraud's dextrose agar (SDA) plates, in duplicates. The mixture was evenly spread on the medium. The agar plates were incubated at ambient temperature of 25-27°C for 48 h (NA Plates) or at 37°C for 24 h (NA plates) or 72 h (BA plates) and at 28°C for 5-7 days (SDA Plates).

Bacterial isolates were identified in accordance with the schemes of Baron and Sydney (1990) and the Bergy's Manual of Determinative Bacteriology (Holt *et al*., 1994) while the fungi were identified using the needle mount method of Cheesbrough (1991) to observe the reproductive structures. Final identification of isolates was done by comparing the results of the cultural and morphological characteristics with those of known taxa (Baron and Sydney, 1990; Olds, 1983).

RESULTS AND DISCUSSION

Physico-chemical parameters: Temperature of soils at various depths within the waste collection sites ranged from 24.5 to 28 (Table 2). Increase in temperature above permissible limits can lead to decrease in the dissolved oxygen level while increasing the biological oxygen demand of organisms in that soil region. The pH values recorded ranged between 3.3 to 7.3. Weiss (1974) and Bonarius (1975) recognized that strongly alkaline and strongly acid soils are unsuitable for waste dumpsites. The soils of the Club Road (Station 3) were extremely acidic with mean pH of 3.3 and 3.6. At such levels there tends to be an increased micronutrient solubility and mobility as well as increased heavy metal concentration in the soil (Kumar, 1987) thus rendering them unsuitable for waste dumpsites.

A high level of organic matter (2.03%) was found to be conducive for heavy metal chelate formation, increased exchange capabilities as well as increased infiltration of surface water to avoid surface flooding (Ekundayo and Fagbami, 1996; Ekundayo, 2003).

The mean textural class for the soils at the various stations was predominantly sandy loam. Excessive and low sand fractions (>70% and <40%) as observed in stations 1,2,3,5,6,7 and 8 soils make the soils non-suitable for waste dump sites in Port Harcourt city (Loughry, 1973) since they are rapidly permeable and could allow large quantities of leachates from the decomposed waste to invade the groundwater table. When a landfill area is underlain by gravel, there is extreme hazard of pollutants being carried down to the underground water. Sand has a high percolation rate but does not provide sufficient protection against grounds water pollution

Similarly, most of the stations did not meet textural requirement for waste collection sites/depots since they contain mean clay fraction greater than 31%. High clay concentration (>31%) encourages surface water flooding and pollution (Ekundayo, 2003). Surface water that infiltrates the soil cover increases the rate of waste decomposition and eventually causes a leachate to leave the solid waste and create pollution problems (Ekundayo and Fodeke, 2000). For cover materials, soils with very

Table 2: Physico-chemical characteristics of the waste collection sites in Port Harcourt City

Physico-chemical parameters	Station 1 mile 1 market		Station 2 elechi street mile 3		Station 3 club road		Station 4 harold wilson drive borikiri	
	0-15	105-120	0-15	105-120	0-15	105-120	0-15	105-120
Temp.(°C)	27	26.5	27	27.4	28	27	27	27
pH	7.30	7.0	5.9	5.0	3.6	3.3	6.3	6.2
Phosphorus (mg L^{-1})	30.82	39.84	118.20	22.93	45.67	23.87	50.18	89.83
% Organic carbon	0.67	1.22	2.01	1.42	1.45	0.71	3.58	2.12
% Organic matter	0.86	1.14	1.06	2.03	1.96	1.82	1.15	1.02
% Sand	77	59	79	69	73	48	68	68
%Silt	10	6	10	2	16	9	23	10
%Clay (wet)	13	35	11	29	11	43	9	22
Textural Class	SL	SCL	SL	SCL	SL	SC	SL	SCL

Table 2: Continued

Physico-chemical parameters	Station 5 garri market moore house street		Station 6 new layout market		Station 7 behind ibru fisheries D/Line		Station 8 aggrey road by police children's school	
	0-15	105-120	0-15	105-120	0-15	105-120	0-15	105-120
Temp. (°C)	27	26.5	24	28	27.5	26	28	24.5
pH	6.8	6.4	5.7	5.5	6.4	6.4	5.9	5.1
Phosphorus (mg L^{-1})	48.30	29.69	27.25	21.05	34.30	30.43	32.84	29.90
% Organic carbon	1.89	1.34	0.98	1.53	1.90	1.34	2.49	1.98
% Organic matter	1.06	1.74	1.50	1.26	1.30	1.62	1.48	1.67
% Sand	84	84	75	65	62	84	74	64
%Silt	13	9	13	12	15	10	12	6
%Clay (wet)	3	7	12	23	3	6	4	30
Textural Class	SL	SL	SL	SCL	SL	SCL	SL	SCL

Key: SL = Sandy Loam, SCL = Sandy clay loam, SC = Sandy clay

Table 3: Concentrations (mg l^{-1}) of metals in selected refuse collection points/sites in Port Harcourt City

	Metals (mgl^{-1})	Permissible limits (mgl^{-1})	Stations 1	2	3	4	5	6	7	8
Soil samples	Zn	3.0	3.4	5.39	3.89	1.985	1.975	2.465	3.6	3.77
	Pb	0.01	0.845	0.69	0.59	0.45	0.365	0.65	0.305	0.605
	Cr	0.05	0.06	0.25	0.085	0.065	0.075	0.07	0.035	0.11
	Cd	0.003	ND	ND	ND	0.03	ND	ND	ND	ND
Boreholes (water samples)	Zn	3.0	0.286	0.300	0.281	0.330	0.240	0.223	0.297	0.186
	Pb	0.01	ND	ND	0.0065	0.016	0.001	0.015	0.001	0.0065
	Cr	0.05	0.021	0.0275	0.02	0.0165	0.235	0.032	0.018	0.0195
	Cd	0.003	ND	ND	ND	ND	ND	ND	ND	ND

Permissible limits (WHO, 1998); ND-Not detected

friable and friable consistence are good; soils with loose and firm consistence are fair while soils with extremely firm consistence are poor (Loughry, 1973). Good soil texture for cover materials includes sandy loam silt loam and sandy clay loam.

Concentration of metals: Results obtained in this study revealed that concentration of toxic metals in the soil samples were above recommended permissible limits in all the stations (Table 3). This indicates that leachate from the decomposed waste carries high concentration of toxic inorganic contaminants that can cause severe pollution of the soils. The higher concentration of these toxic metals can also be mixed up with ground water after leaching and may cause a number of water borne diseases. Therefore it is suggested that the treatment of waste materials to remove or minimize pollution before disposal into the environment is important and ensures safety of the populace. This is because poorly suited soils may cause irreparable damage to land and water resources. Hence sand and silt mixed in proportion would be a more acceptable soil system for waste treatment (Kumar, 1987).

The quality of water may be described in terms of the concentration and state (dissolved or particulate) of some or all of the organic and inorganic materials present in the water, together with certain physical characteristics of the water (NSWQC, 1994). Therefore, toxic chemicals in drinking water may cause either acute or chronic health effects. Acute effects such as nausea, lung irritation, skin rash, vomiting, and dizziness and in the extreme, death usually follow large doses of chemicals and occur almost immediately. Chronic effects like cancer, birth defects, organ damage, disorder of nervous system and damage to the immune system are usually common (Erah *et al*., 2002). Although the result of this study indicates that the presence of concentrations of metals contaminants in the water samples are below permissible limits, it cannot be assumed that the water resources within the waste collection sites are portable enough because even at low concentrations metal can be detrimental to health and also imparts an undesirable taste to drinking water. It is unlikely too that the situation in most other areas of the city will be significantly different as the living standards and activities are similar in most parts of the city which is under lain by the same formation.

Microbial contaminants: According to Erah *et al*. (2002) the presence of certain microorganisms is often undesirable in any drinking water. When microorganisms are present in water, cycles of growth and decay of the cellular materials of the microorganisms may result in the production of by-products, which may adversely affect the quality of the water supply. This is also true regarding the growth cycles of other non-pathogenic bacteria and harmless microorganisms (Rhode and Hartmann, 1980). Most drinking waters from boreholes in most parts of Port Harcourt city are unlikely to be treated in any way before they are ingested. Thus the presence of pathogenic microorganisms such as *Streptococcus, E.coli; Pseudomonas, Bacillus, Micrococcus, Klebsiella, Staphylococcus, Chromobacterium, Proteus and Serratia species* and fungi in the different boreholes from different stations is a major concern for consumer because of the effect of the microorganisms on the health of the consumers. Coliforms are a group of bacteria with common characteristics used to indicate unacceptable water quality. Within the total coliform group, *E. coli* bacteria are specifically used to indicate fecal contamination (Erah *et al*., 2002). In Port Harcourt city, public boreholes are sited without proper geological surveys. Indiscriminate refuse and waste disposal and location of septic tanks soak-away pits and pit latrines in living surroundings especially Diobu area is common. These activities could account for the presence of fecal bacteria in the borehole waters.

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