

Impact of Municipal Wastes on the Water Quality around Rumuola Borrow Pit, Rivers State, Nigeria

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Abstract— The impact of municipal wastes dumped into the Rumuola Borrow Pit on the surface and ground water quality of its environment was assessed by analyzing the physicochemical parameters, polycyclic aromatic hydrocarbons (PAHs) and heavy metals from adjoining boreholes and surface water from the borrow pit. The deposition and decomposition of municipal wastes led to an increase in acidity, BOD₅ concentrations (4.9mg/l), Turbidity (13 NTU) and NO₃-N values [<0.05 mg/l – 0.15 mg/l (mean 0.085 mg/l)]. Analysis of Variance results showed similar trends for most parameters during the dry and wet season. Dissolved Oxygen depletion downstream is a clear indication of the impact of these municipal wastes. Surface and ground water around the borrow pit was screened for the presence of 16 Polycyclic Aromatic Hydrocarbons (PAHs) by Gas Chromatography with flame ionization detector (GC/FID). PAHs components recorded in the surface water ranged between 112 µg/l and 133 µg/l). PAHs were not detected in the boreholes implying that they are not being impacted by the water quality of the borrow pit. The Molecular Ratios (Phenanthrene/Anthracene) and (Fluoranthrene/Pyrene) determined the sources of PAHs found in the Rumuola Borrow Pit as pyrolytic and petrogenic.

Index Terms— Rumuola Borrow pit, water quality, physico-chemical properties, heavy metals and polycyclic aromatic hydrocarbons (PAHs).

I. INTRODUCTION

Municipal wastes refers to all categories of wastes including garbage (food waste), rubbish, yard wastes, street sweeping, ashes, industrial wastes, dead animal and man, abandoned vehicles, hazardous wastes, demolition debris, hospital disposables, construction wastes, garage crankcase oil and acids (Onwughara *et al.*, 2010) disposed of by a municipality. Increased population in coastal towns like Port Harcourt has resulted in an increase, by several magnitudes, of waste generated (Ayotamuno *et al.*, 2004). In Nigeria as in most other developing nations, waste management has not received the desired attention. In these nations, disposal of solid waste in open dumps is most common (ISWA, 2015). Indiscriminate dumping of municipal wastes can be linked to environmental pollution through the introduction of chemical substances above threshold limit into the environment (Etusim *et al.*, 2013), introduction of additional heavy metal into surrounding soil and groundwater (Arimieari *et al.*, 2014), growth of populations of insect vectors and rodents that transmit various kinds of diseases (ISWA, 2015), generation of unhealthy odours by the uncontrolled release of methane and carbon dioxide (biogas) from decaying organic

substances or anaerobic decomposition (Ngah, 1993), devaluation of property and infrastructure (Wokekoro and Uruesheyi, 2014); reduction of aesthetic beauty of the environment (Ukpong *et al.*, 2015) and initiating road accidents by obstructing the flow of traffic. Municipal waste disposal into un-engineered open dumps can be a major cause of public health problems. As refuse decay, it produces a highly polluting substance called leachate. Under shallow water table conditions typical of the Niger Delta easily percolate downward to reach the shallow water table resulting in contamination of groundwater.

Water quality degradation expected of leachate contamination is generally in the form of increases in total hardness, Ca²⁺, Mg²⁺, Na⁺, K⁺, Cl⁻, SO₄²⁻. Other parameters such as NH₄⁺, N₂, Fe²⁺, COD, BOD may also increase. However, as leachate migrates in natural geologic materials, a number of physico-chemical processes take place leading to attenuation of potency, dilution and over-all reduction in concentration of contaminants (Ngah and Abam 2006). The extent of groundwater contamination also depends on the hydrogeologic characteristics of the site and on whether the waste dump is located at or near the discharge or recharge parts of the aquifer

II. DESCRIPTION OF THE STUDY AREA

The Rumuola Borrow Pit is located at the vicinity of an oil location in Port Harcourt, Rivers State and situates between longitudes E 007° 00' 01.0'' to E 007° 03' 09.7'' and latitudes N 04° 50' 08.5'' to N 04° 50' 14.2'', Figure 1. The climate is typical of the Equatorial Tropical Latitude. Temperature ranges from a minimum of 21.2 - 23.2 °C and a maximum of 28.7 - 33.4 °C. Annual rainfall averages 2,480 mm. Rumuola Borrow pit is located in a high density area of the oil-rich Port Harcourt. The pit is a void created as a result of laterite/sand mining for road construction 32 years ago. It has formed a large pond of water covering an area about 135,000 m² with a depth of about 7.68 m. Depth to the ground water table in the area is 7.49m implying that the pit cuts into the regional water table. The inhabitants put the large body of water to various uses such as washing, bathing, swimming and fishing. Plates 1-5 show activities in the pit and various uses to which the burrow pit is put.

This study was stimulated by a concern for the health implication of this water body and was carried out to evaluate the surface and groundwater qualities in the vicinity of the burrow pit. The aim of this study was to examine the possible impact of municipal wastes dumped into the borrow pit on the surface water and adjoining ground water quality. The specific objectives are to determine the physico-chemical characteristics of the water, concentrations of specified trace metals and Polycyclic Aromatic Hydrocarbons (PAHs) in the

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surface water and adjacent water boreholes and also to provide baseline data on the water quality around the Borrow pit with a view to making recommendations on its suitability

for different uses and possible health implications of its use or misuse.

Fig. 1: Map of the study area (Rumuola Borrow Pit)

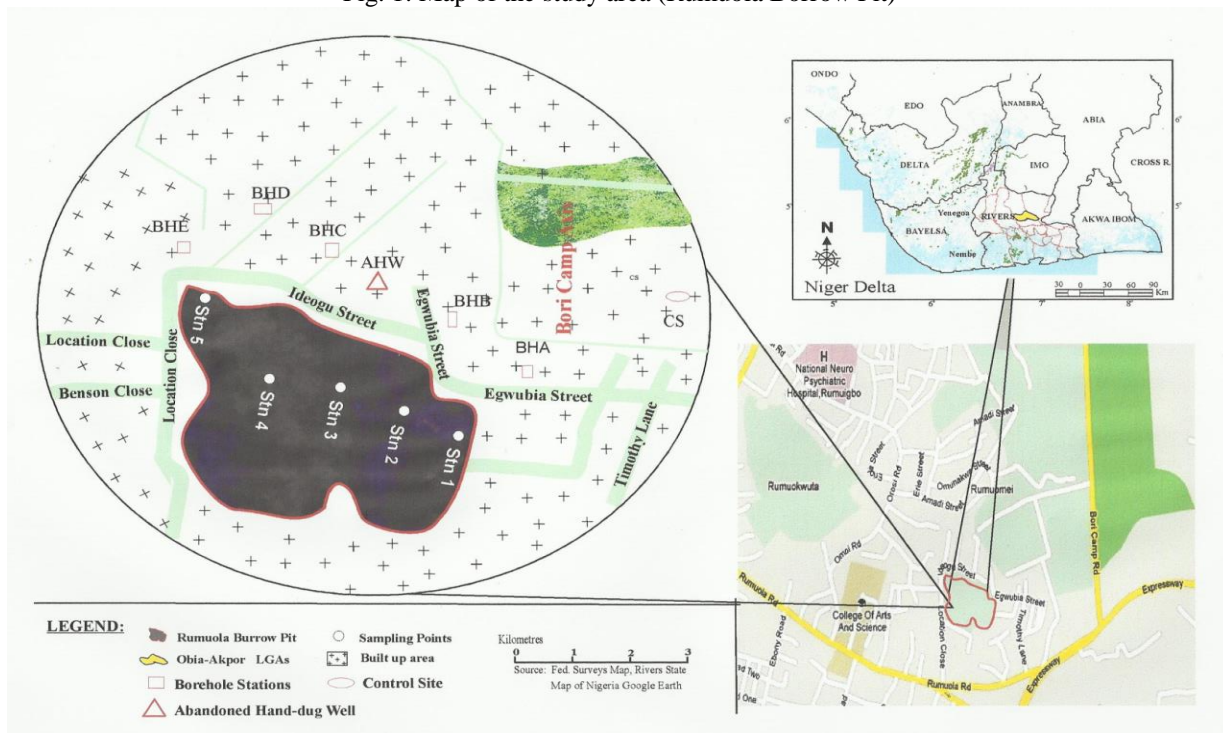


Plate 1: Municipal wastes dumped into the Borrow Pit (sewage pipes channeled directly into Borrow Pit)



Plate 2: Burning of wastes around the borrow pit results in air pollution



Plate 3: Scavengers at work around the Rumuola Borrow Pit



Plate 4: Project site during the rainy season



Plate 5: Roots of trees partly exposed in the dry season

III. MATERIALS AND METHOD

The study involved desk research, field work and laboratory analyses. A reconnaissance visit was made to the site to establish the dimensions and actual field conditions of the site. The visit also served to ground-truth the reports from desk research. During actual field work, five sampling stations were established within the water body ($BP_A - BP_E$). Five water borehole were located close to the pit were chosen udy ($BH_A - BH_E$). Water samples were collected from a hand-dug well adjacent Borrow Pit and named Station C. A control station was established 300 m upstream of the dumpsite. Observations and sampling commenced in August 2010 and allowed to continue through the two major seasons in the area namely the wet and dry seasons. The study site coordinates are shown in table 1.

Table 1: Sampling points and their coordinates

S/No.	Code	Coordinates	
		Northing	Easting
1	BPA	04°50'08.5"	007°00'01.0"
2	BPB	04°50'13.8"	007°00'02.1"
3	BPC	04°50'12.2"	007°00'06.4"
4	BPD	04°50'10.2"	007°00'09.7"
5	BPE	04°50.172'	007°00'01.0"
6	BHA	04°50'06.8"	006°59'59.6"
7	BHB	04°50'15.7"	007°00'02.6"
8	BHC	04°50'14.2"	007°00'07.7"
9	BHD	04°50'10.0"	007°00'13.1"
10	BHE	04°50.166'	007°00.219'
11	CS	04°50.164'	007°00.180"
12	AHW	04°50'13.8"	007°00'10.2"

*B P - Borrow Pit Station; BH - Borehole; CS - Control Station; HDW – Hand Dug Well.

Table 2 shows the methods adopted in sampling and analysis of samples. Physico-chemical parameters, Heavy Metals and Polycyclic Aromatic Hydrocarbons (PAHs) were analyzed in Surface Water and Ground Water samples.

Table 2: Field and laboratory methods for analyzing pollution indication parameters

Parameter	Field and Laboratory Method
Temperature	Mercury-in-glass thermometer
pH value	Horiba multiprobe U-10 water checker
Dissolved Oxygen (DO)	Winkler method (Stirling, 1999)
Biochemical Oxygen Demand (BOD_5)	Winkler's method
Sulphate	Spectronic Spectrophotometer 21D – Turbidimetric method
Phosphate	Spectronic Spectrophotometer 21D – Stannous Chloride method
Nitrate-Nitrogen	Brucine method
Heavy Metal	Atomic absorption spectroscopy (AAS)
Polycyclic Aromatic Hydrocarbon (PAH)	Gas Chromatographic (GC) method using Flame Ionization Detector (FID)

Samples were collected in appropriate containers, labeled and transported to the laboratory of the Institute of Pollution Studies (IPS), Rivers State University of Science and Technology, Port Harcourt for analysis. Standard analytical methods were adopted for all the physicochemical analysis (APHA, 1998).

IV. DATA ANALYSIS

Statistical tools such as mean, standard deviations and variance were used to analyze the data obtained to ascertain how representative and close the data were. Two-way analysis of variance (ANOVA) and Students T-test analysis were used to show temporal variations and also to determine significant difference between the stations and months/seasons of sampling. Bar charts and multiple bar charts were employed in result presentation. Correlation coefficient was calculated to highlight the relationship between the parameters.

V. RESULTS

(a) Surface water

For surface water, temperature values were higher in the dry seasons 26.90°C - 30.7°C (mean 27.78°C). pH values were slightly acidic in the dry season 6.4 – 6.7 (mean 6.58) and neutral to slightly alkaline 7.1 – 7.5 (mean 7.30) in the wet season. Conductivity levels were within the WHO desirable limit of 500µS/cm for drinking water. Sampling point E showed the highest value for Turbidity (13 NTU) in the rainy season. Dissolved Oxygen (DO) concentration was higher in the dry season with values between 2.8mg/l and 7.3mg/l (mean 4.89 mg/l). Biochemical Oxygen Demand (BOD₅) test results ranged from 0.8mg/l – 4.9mg/l (mean 2.38 mg/l) in the rainy season. The Hardness levels were higher in the wet season at 46.1 mg/l as CaCO₃ – 76.8 mg/l as CaCO₃ (mean 66.74 mg/l as CaCO₃). Sulphate had the highest concentrations amongst the nutrient variables during the dry season and ranged from 3.8 mg/l – 14.7 mg/l (mean 6.24 mg/l). Phosphate concentrations were higher (<0.05 mg/l – 0.05 mg/l) in the wet season and sampling E had the highest values. Nitrate –Nitrogen (NO₃-N) had higher concentrations <0.05 mg/l – 0.15 mg/l (mean 0.085mg/l) in the wet season. Chromium concentrations recorded were within the permissible limits of potable water (0.05 mg/l). All stations measured <0.003 mg/l of chromium in both seasons. Concentrations of Cadmium concentrations ranged between <0.01mg/l – 0.008 mg/l (mean 0.029 mg/l) and <0.003 mg/l – 0.004 mg/l (mean 0.0005 mg/l) for the dry and wet season respectively. Mean concentrations of Iron detected were above the permissible limits. Lead concentrations were higher in the wet season < 0.001 mg/l – 0.230 mg/l (mean 0.044 mg/l) than in the dry season < 0.001mg/l for all stations. Most values exceeded the permissible limits of 0.01 mg/l (Table 3).

The concentrations of total Polycyclic Aromatic Hydrocarbons (Σ PAHs) in surface water ranged from 112 – 133 µg/l (mean 122.830 µg/l). Σ PAH concentration of the seven carcinogenic PAH compounds in surface water ranged from 73.703 – 128.222 µg/l (mean 108.270 µg/l). Benzo(b)Fluoranthene and Indeno(1,2,3,cd)Pyrene had the highest concentrations. They are carcinogenic PAHs. In Surface Water: SWA - Acenaphthylene and SWC – Benzo(b)Fluoranthene were not detected (Table 4).

(b) Ground Water

For groundwater, temperature values ranged varied from 26.9°C – 29.6°C (mean 27.6°C) and 22.6°C to 28°C (mean 25.12°C) for the dry and wet seasons respectively. Hydrogen ion (pH) ranges in the dry and wet seasons were 3.82 – 6.7 (mean 4.49) and 4.55–7.9 (mean 5.09) respectively. Mean Conductivity levels for the dry season was higher [16.8 µS/cm

– 585 µS/cm (mean 125.88 µS/cm)] than in the wet season (49 µS/cm - 278 µS/cm (mean 113.16 µS/cm)].

The highest levels of Cadmium concentrations were recorded in Borehole E (0.007mg/l) and above the W.H.O. permissible limits of potable water (0.3 mg/l). Cadmium showed non-significance with other variables. Chromium concentration was <0.003mg/l for all stations and were within the permissible limits of potable water. Lead concentrations were higher in the wet season. Concentrations of Iron found in most of the boreholes were within the permissible limits of potable water

The total Polycyclic Aromatic Hydrocarbons (Σ PAHs) concentrations in the water sample collected from the abandoned hand dug well was 4.365 µg/l. Σ PAH concentration of the seven carcinogenic PAH compounds was 4.337 µg/l. No PAHs was detected in the borehole samples.

VI. DISCUSSION

(a) Surface Water

The surface water temperature values were generally high. The dry season recorded higher temperatures (26.90°C - 30.7°C) typical of the Niger Delta region. This was attributed to its location at the equatorial latitude where ambient temperature is consistently high all year round (Egborge and Benka-Coker, 1986). At leachate inflow points, lower pH values were observed. These lower pH values resulted from high acidic substances dumped and subsequently hydrolyzed. This indicated that activities at the dump site resulted to increased acidity in the borrow pit. Organisms living in the habitat would be adversely affected and biodiversity disrupted as a result of the altered pH (Umunnakwe *et al.*, 2009). Conductivity concentrations were higher in the wet season (mean range 233.50 µS/cm – 252.50 µS/cm) when compared with the dry season. This result is in agreement with works of Chindah, *et al.*,(2005) for Agbonchia and Ntawogba streams in Port Harcourt. Most Turbidity values determined during the rainy season exceeded WHO (2006) permissible limit of 5NTU. This is explained as resulting of run-off through the dumpsite into the borrow pit during rainy season. The BOD₅ concentration serves as a measure of organic pollution in water bodies. Based on this criterion and applying Moore and Moore (1976) ranking, the state of the water body in the burrow pit can be classified as ‘doubtful’ (Table 3). BOD₅ concentrations increased downstream in both wet and dry seasons.

Table 3: Biochemical Oxygen Demand Levels and the State of the Water Body (Moore and Moore Ranking, 1976)

S/No.	BOD levels (mg/l)	State of Water body
1	1.0 – 2.0	Clean
2	< 3.0	Fairly Clean
3	< 5.0	Doubtful
4	10.0	Bad and Polluted

Nutrient parameters (Sulphate, Phosphate and Nitrate-Nitrogen) were below W.H.O., 2006 permissible limits. However, higher concentrations of Phosphate at the

borrow pit station E may be as a result of the impact of the waste discharges but organisms in tropical water bodies quickly use up these nutrients under high temperature conditions (Chindah *et al.*, 2005). Nitrate –Nitrogen (NO₃-N) had higher concentrations above the EPA permissible limits of 0.1mg/l. This high level showed the presence of organic pollution (from human or animal wastes). A positive significance was observed with Turbidity ($r^2 = 0.54$), Sulphate ($r^2 = 0.98$), Phosphate ($r^2 = 1.00$) and Zinc ($r^2 = 0.96$) in the wet season. All nutrient variables displayed similar trends in correlation significance in both seasons.

Chromium had a positive significance with pH ($r^2 = 0.88$), Conductivity ($r^2 = 0.98$), DO ($r^2 = 0.54$), BOD₅ ($r^2 = 0.63$), Hardness ($r^2 = 0.78$), Cadmium ($r^2 = 0.57$) and Iron ($r^2 = 0.57$) in the dry season. Cadmium concentrations recorded in the dry season (Borrow Pit Station A - 0.004 mg/l and Borrow Pit Station E - 0.008 mg/l) exceeded the permissible limit of 0.003 mg/l WHO (2006) and could have adverse effects on the kidneys of human beings. In the dry season, Cadmium showed negative significance with most variables with exception of pH ($r^2 = 0.52$), Conductivity ($r^2 = 0.62$) and Chromium ($r^2 = 0.57$). Iron concentration was higher than the WHO (2006) permissible limit of 0.3mg/l. These could have resulted from external contamination or breakdown of crustal material rich in Iron content. It showed similar trends in significance like Chromium with exception of DO and Cadmium that were not significant during the dry season. Lead concentrations were higher in the wet seasons for most stations compared to the set W.H.O. limit (0.01 mg/l). Borrow Pit Station C had the highest value of 0.230mg/l. These high levels were attributed to anthropogenic enrichments arising from domestic effluents and wastes from the auto-mechanic workshop as well as surface run-off from dumpsites in the area. Lead is the most toxic of the heavy metals. Its inorganic forms are absorbed through ingestion by food, water and inhalation. In humans, exposure to Lead can result in a wide range of effects depending on the level and duration of exposure. High levels of exposure may result in cancer; interfere with Vitamin D metabolism; problems in the synthesis of haemoglobin; effects on the kidneys, gastro-intestinal tract, joints, reproductive system and acute or chronic damage to the nervous system (NIS, 2007, Duruibe *et al.*, 2007). Zinc concentrations were higher in the dry seasons. It exhibited a trend different from that of the other metals assessed.

Station A in the borrow pit had the highest total PAH concentration (Σ PAHs^c 132.951 μ g/l; Σ PAHs^b 128.222 μ g/l). About 96% of the PAH concentration consisted of the carcinogenic compounds. Benzo(b)Fluoranthene, a carcinogenic component, harmful to humans, had the highest concentration. Benzo(a)pyrene had the highest concentration in Borrow Pit Station B (1.790 μ g/l) exceeding the W.H.O. recommended value of 0.70 μ g/l for drinking water. This corresponded to an excess lifetime cancer risk of 10⁻⁶ documented by Anyakora *et al.*, in (2004). Most of the PAH components exhibited strong positive significance with each other.

(b) Ground Water

Groundwater temperature values were generally high and typical of the equatorial tropical latitude. The pH ranges from acidic in the dry season to neutral in the wet season. The concentration of Total Hardness in samples collected from

Bore Hole Station E exceeded the WHO desirable limit of 150mg/l as CaCO₃ denoting hard water not suitable for laundry. Borehole station A showed conductivity levels of 585 μ S/cm that exceeds the EPA permissible limits but with no health implications. On the basis of Moore and Moore (1976) ranking, BOD₅ concentrations showed the ground water state as 'fairly clean'. It is advised that the water quality in BHA and BHB with Nitrate-Nitrogen concentration of 0.76mg/l and 1.32 mg/l respectively be checked periodically. Concentrations as low as 10 to 20 mg/l have caused illness and even death among infants under six months of age. It results in oxygen starvation called methemoglobinemia ("blue baby") condition (Husaini *et al.*, 2007). All nutrient parameters had values above the W.H.O. permissible limits of 0.1mg/l indicating the presence of organic pollution from human or animal wastes.

Cadmium levels in Borehole E was 0.004 mg/l which is higher than the WHO (2006) permissible limits of 0.003 mg/l. This concentration could possibly affect the kidneys of human beings (Ogbonna *et al.*, 2006). The high proportion of Lead in the sampled boreholes indicates Lead contamination.

No PAHs was detected in the borehole samples indicating that the water is safe for consumption, based on this criterion.

Molecular Ratios as determinants of sources of PAHs

Molecular indices based on ratios of individual PAH levels in water can be used to distinguish PAHs from pyrolytic/pyrogenetic (e.g. fossil fuel combustion and vegetation fires) and petrogenic/petroleum (e.g. oil spill and petroleum products) input. In this study, two ratios were used to indicate the source of PAHs.

1. Phenanthrene (Phe) / Anthracene (Ant)
2. Fluoranthene (Flu) / Pyrene (Pyr)

For petrogenic origin ; Phe/Ant > 10 and Flu/Pyr < 1

Pyrolytic origin; Phe/Ant < 10 and Flu/Pyr > 1

From the study, it can be concluded that the PAHs are of both pyrolytic and petrogenic origin since Phe/Ant < 10 (mean value 1.660) and Flu/Pyr < 1 (mean value 0.030) in surface water for all stations.

VII. CONCLUSION

Depletion of the Dissolved Oxygen downstream in surface and ground water are clear indications of the impact of these municipal wastes dumped indiscriminately into the Rumuola Borrow Pit.

PAHs found in the Rumuola Borrow Pit are of pyrolytic (e.g. fossil fuel combustion and vegetation fires) and petrogenic (e.g. oil spill and petroleum products) origin as indicated by the molecular indices – Phenanthrene /Anthracene and Fluoranthene / Pyrene. Concentrations of the low molecular weight (LMW) PAHs such as Naphthalene, Acenaphthylene, Acenaphthene, Pyrene, Fluoranthene, Fluorene, Phenanthrene, Chrysene, Benzo(a)Anthracene and Anthracene were found to be lower than that of the high molecular weight (HMW) PAHs which includes Benzo(k)Fluoranthene, Benzo(b)Fluoranthene, DiBenzo(a,h)Anthracene, Benzo(g,h,i)Perylene, Indeno(1,2,3-cd)Pyrene and Benzo(a)Pyrene.

Benzo(b)Fluoranthene and Indeno(1,2,3-cd)Pyrene had the highest concentrations. Most of the PAHs like Benzo[a]Anthracene, Chrysene, Benzo[b]Fluoranthene, Benzo(g,h,i)Perylene have properties that are carcinogenic hence dangerous to health.

Since PAHs were not detected in water samples from boreholes, it is safe to assume that the boreholes are not in hydraulic contact with the water in the borrow pit.

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