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Physiochemical Analysis of Municipal Solid Waste Leachate from Open Dumpsites in Benin City Metropolis

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ABSTRACT: Physiochemical assessment of leachate in three open dumpsites in Oluku, Uselu and New Benin in Benin City was carried out in this study using standard methods. The pH of leachate sample from Oluku dumpsite was ultra-acidic (3.4) with electrical conductivity of 1650 µS/cm. However pH of leachate samples (7.4 and 8.6) collected from Uselu Market dumpsite and New Benin dumpsite were in the alkaline range with electrical conductivity of 8600 and 9800 µS/cm. The aforementioned approach was employed at distances of 2m and 5m from the mid-sections of these dumpsites and pH of leachate at a distance of 5m from the three were observed to be in the neutral range. The physiochemical analysis indicated the hazards of open waste dumping, as leachate in these dumping sites contains ammonia, calcium carbonate, nitrate, sulphate and other heavy metals which can percolate and contaminate surface water and ground water thereby, causing negative effects on public health safety and the environment.

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Waste can be regarded as unwanted or unusable material that cannot meet its primary function as well the needs of the owner and therefore disposed of. However, it is seen that a material that is considered as waste in one process is a key element in another process, therefore creating a cycle. For example, humans breadth in oxygen (O_2) and breadth out carbon dioxide (CO_2) while plants utilize the CO_2 during photosynthesis and release oxygen (Ikpe and Owunna, 2016; Ikpe and Owunna, 2017). Recent studies indicate that most countries are beginning to redefine waste as a potential resource which have economic value when processed adequately, hence, laws and policies are being made to ensure that all waste generated is utilized for economic benefit and growth (Ikpe *et al.,* 2019; Ramatta *et al.,* 2014; Sunii *et al.,* 2017). Nigeria with a population of over 200 million people generates waste at a rate of 0.43kg/head per day and 60-80% of it is organic in nature (Onyelowe, 2017). Municipal Solid Waste (MSW) generated in Nigeria is over 26-32 million tons annually, out of which only 20-30% is collected (Chima *et al.,* 2016). Proper and adequate waste management is necessary in the process of converting waste to economic value; however, waste is mismanaged as seen in its indiscriminate disposal in public and private places. Environmental and public health related risks associated with indiscriminate disposal of wastes have raised concerns about the mismanagement of waste in Nigeria. Waste mismanagement in Nigeria has largely been attributed to little knowledge about the economic benefits of processed waste and the availability of machines used in processing waste to add value to it (Afangide *et al.,* 2012). The R3 (Reduce, Reuse and Recycle) system of waste management is one of the most effective methods of managing different types of waste, but this system is rarely applied in Nigeria (Awopetu *et al.,* 2012), rather, waste management characterized by open dumping, open dumpsites, indiscriminate disposal of waste materials by the road side and even disposal near drinking water sources is the common means of waste disposal (Joseph *et al.,* 2016; Ochuko, 2014; Abdullahi *et al.,* 2014; Emankhu and Yamusa, 2017). This practice leads to environmental dilapidation as well as the formation of leachate, a black liquid containing organic and inorganic chemicals, heavy metals as well as pathogens, which can pollute groundwater and surface water causing public health risks. Exposure of humans to leachate contaminated waters can lead to diseases like diarrhoea, cholera, skin diseases, respiratory allergies, malaria, tuberculosis, jaundice cancer from the pathogens in the leachate and Lassa fever which is reported to be caused by a vector known as *mastomys natalensis* (Ikpe *et al.,* 2018). There is a high risk of contamination and spread of most of the diseases as they are communicable through humans and animals

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such as rats, flies, birds and even humans who find refuge in open dumpsites, becoming a source for spreading such communicable diseases (Samuel *et al.,* 2016). Leachate is formed when water mixes with decomposing waste mostly at open dumpsites (Kurniawan *et al.,* 2006). The biodegradation of organic matter in open dumpsites interacts with other inorganic waste materials, yielding different compositions of leachate. Municipal landfill leachate is a highly concentrated effluent which contains dissolved organic matter and inorganic compounds classified as water-based solution of four groups of pollutant i.e. dissolved organic matter, inorganic macro components, heavy metals and xenobiotic organic compounds (Agbozu *et al.,* 2015). Concentration of leachate depends on the age of the waste, waste density, water content, type of waste, humidity, rainfall, climatic and hydrogeological conditions and the rate at which surface water percolates into the dumpsite (Andrzej, 2011). Leachate at the bottom of the dumpsite impact negatively on the soil surface and to adjacent areas, percolating through the soil and undergoing various processes such as physiochemical process, ion exchange reactions, chemical alterations, oxidation and hydrolysis which alter the soil original properties (Nwaka *et al.,* 2018). Soil pH is an important soil property which is the measure of the soil solutions acidity and alkalinity (Ann, *et al.,* 2017). It is one of the factors which influence the transportation of contaminants in an environment as well as the availability of micronutrients and heavy metals in plants. Increasing acidity (low pH value) can cause some metals to dissolve in water thereby releasing toxic elements that may pollute groundwater; conversely, decreasing acidity (high pH value) can cause certain soil nutrients to become insoluble and thereby unavailable for plant growth (Nwaka *et al.,* 2018; Moses *et al.,* 2016).

The risk of groundwater contamination in Nigeria is one of the environmental challenges posed by open dumpsites, as they are sited indiscriminately without government approval and operated unprofessionally and without engineered lining and leachate collection systems. Open dump sites are a threat to the health, wealth and environment and steps must be taken to ensure that the act is eliminated. This investigation was aimed at analysing the physiochemical content of municipal solid waste leachate from open dumpsites in Benin City Metropolis.

MATERIALS AND METHODS

Different sample waste was collected from each waste batch brought in by waste management trucks to the various dumpsites visited which was sorted and characterized according their classification before measurement. The classification of waste characterised from each of the dumpsites consisted of organic and inorganic waste materials.

Leachate from the mid-section of Uselu Market and New Benin dumpsites was collected at the surface of the dumpsites as shown in Figure 1a and Figure 1b, while the hole where the other sample was collected was dug at a depth of 1 meter at the mid-section of Oluku dumpsite as shown in Figure 1c. Holes of 1m were also dug at a distance of 2m and 5m from the mid-section of each of the three dumpsites, and leachate was collected from the dug holes after 12 days of rain which had mixed with the waste stream. Leachate samples from the mid-section, 2m and 5m from the mid-section of each dumpsites were collected with 50ml sample bottles as shown in Figure 2a, Figure 2b and Figure 2c respectively. The pH and electrical conductivity of the leachate samples were recorded on site using digital pH meter (pH-2011) and digital electrical conductivity meter (PCE-SM11). The samples were stored in a cooler containing ice block to maintain a temperature below 5^{o}C and were then transported to the laboratory for analysis. Total iron, nitrate and phosphate were determined by molecular absorption spectrometry method. The concentration of heavy metals was estimated by direct air acetylene flame method using the Atomic Absorption Spectrophotometer Model (SL168 Elico, India).

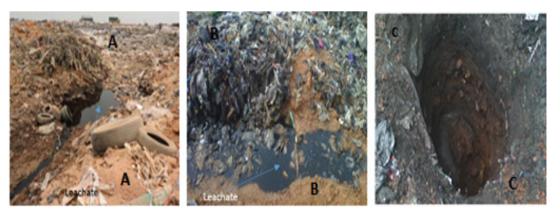

Fig 1: Leachate accumulating in dumpsites and dug hole for leachate collection. (a) Uselu market. (b) New Benin market. (c) Oluku dumpsite

Fig 2: Leachate samples collected from Oluku, Uselu market and New Benin dumpsites

Figure 2a represent leachate samples collected in the morning and evening at the mid-section of each of the three dumpsites. Figure 2b represent leachate samples collected in the morning and evening at a distance of 2m from the mid-section of each of the three dumpsites. Figure 2c represent leachate samples collected in the morning and evening at a distance of 5m from the mid-section of each of the three dumpsites.

RESULTS AND DISCUSSION

In Benin City, Uselu market and New Benin dumpsites are both located near market premises where most of the items sold are organic-based unlike Oluku dumpsite which is located near commercial and residential area. The analyzed results indicated high concentration of ammonia, nitrate, sulphate and other heavy metals in higher and lower concentrations. This is in agreement with related investigations conducted by Anilkumar *et al.* (2015); Agbozu *et al.* (2015); Nwaka *et al.* (2018).

The waste characterization presented in Table 1 reveals that Uselu, New Benin and Oluku dumpsites have 72%, 64% and 36% of organic waste matter respectively implying that more organic waste matter is generated. The waste characterization also indicated that 21% of waste measured in Oluku dumpsite were metals and 19% were plastics, whereas, 5% of the waste measured in Uselu dumpsite were metals and 13% of the waste constituent were plastics while 6% of the waste measured in New Benin dumpsite were metals and 15% were plastics. Furthermore, 13%, 7% and 10% of paper waste were measured in Oluku, Uselu and New Benin dumpsites respectively while textile (8%) and glass (3%) were also observed to be predominant in Oluku dumpsite.

Table 1: Waste characterization in three major dumpsites in Benin City

Waste Materials (%)	Oluku	Uselu	New Benin
Metals	21	5	6
Organic matter	36	72	64
Glass	3	2	2
Paper	13	7	10
Textile	8	1	3
Plastic	19	13	15

Due to the poor waste management system in Nigeria, waste segregation (sorting) before disposal (Adekunle *et al.,* 2011) is not practiced, hence, organic waste at open dumpsites interacts with other forms of hazardous waste such as battery waste, chemicals and other toxic materials forming leachate with various heavy metals that percolates and contaminate surface water and ground water. According to Dirisu *et al.* (2016), pure water has a pH of 7 which is neutral while pH below 6.8 and above 7.2 is unsafe for drinking. The pH of leachate samples at the mid-section of Oluku dumpsite was 3.4 which is ultra-acidic, 5.8 at 2m from the mid-section of the dumpsite which is acidic and 7.2 at 5m from the mid-section of the dumpsite which is alkaline. However, pH of leachate samples at the mid-section of Uselu Market dumpsite was 7.4 which is, 7.3 at 2m from the mid-section of the dumpsite which is alkaline and 7.1 at 5m from the mid-section of the dumpsite which is also alkaline while pH of leachate samples at the mid-section of New Benin dumpsite was 8.6 which is alkaline, 7.8 at 2m from the mid-section of the dumpsite which is still alkaline and 7.1 at 5m from the mid-section of the dumpsite which is neutral.

Considering the pH of leachate samples from the three dumpsites at different distance, the pH at the mid-section of Oluku dumpsite is ultra-acidic while pH at the mid-section of New Benin dumpsite is alkaline, whereas pH at the mid-section of Uselu Market dumpsite is alkaline. The pH of leachate samples from the three dumpsites at a distance of 2 meters and 5 meters from the mid-section moved towards pH neutrality of 7.0. Leachate with pH values between 1 and 6 indicates the decomposition of organic matter within a body of water, releasing carbon dioxide, which interacts with water to form carbonic acid. Also, the presence of some heavy metals such as aluminium, copper, zinc, lead, calcium, mercury, nickel (as shown in Table 2-4) as well as toxic waste effluent in dumpsites such as calcium oxide and sodium carbonates, produces low pH of leachate as water passes the waste matter. Photoelectric reactions results in the formation of acidic oxides such as SO_2 and NOx, which easily dissolve in water making it acidic. Chemical pollution as a result of waste decomposition in dumpsites can equally reduce water pH. Low pH affects aquatic animals negatively as seen in the formation of mucus on fish gills, retarded growth, and problem with ion regulation as well as reproductive failure Dirisu *et al.* (2016). If leachate percolates groundwater, raising the pH to 8.5 and above, it is an indication that the water is hard. Although hard water does not pose any health risk, it causes the formation of scales on dishes, cooking utensils, and laundry basins, inability of soaps and detergents to lather, and the formation of insoluble precipitates on clothing. Nitrate which is a form of oxidised nitrogen compound was observed in the range of 28.2-36.5 mg/l, 21.3-25.27 mg/l and 6.5-9.2 mg/l in leachate samples collected at the mid-section, 2 m and 5 m of the three dumpsites, indicating the presence of pollutants in all the leachate samples. High level of nitrate concentrations beyond permissible limit may result to the development of cyanosis in infant.

Table 2: Composition of leachate from mid-section of Oluku, Uselu and New Benin dumpsites

Parameters	**Oluku**	**Uselu**	**New Benin**	**FEPA Standard**
pH	3.4	7.4	8.6	6.8-7.2
Electrical conductivity	1650 µS/cm	8600 µS/cm	9800 µS/cm	-
Temperature (ºC)	32.4	32.6	32.3	-
Phosphate (mg/l)	1.72	0.23	0.25	< 500
Sulphate (mg/l)	156	227	243	
Nitrate (mg/l)	36.5	28.2	28.7	< 20
Chloride (mg/l)	958	724	772	< 600
Lead (mg/l)	1.86	0.13	0.21	< 1
Calcium (mg/l)	44	39	41	< 1
Copper (mg/l)	4.82	0.23	1.19	
Iron (mg/l)	27.2	6.34	7.12	< 20.0
Manganese (mg/l)	13.6	0.32	0.41	< 0.50
Mecury (mg/l)	3.42	0.12	0.10	
Cadmium (mg/l)	0.91	0.01	0.01	
Nickel (mg/l)	0.52	0.02	0.04	< 1
Zinc (mg/l)	9.62	7.43	7.67	< 1

Table 3: Composition of leachate collected at 2 m from the mid-section of Oluku, Uselu and New Benin dumpsites

Parameters	Oluku	Uselu	New Benin	FEPA Standard
pH	5.8	7.3	7.8	6.8-7.2
Electrical conductivity	4750 µS/cm	8400 µS/cm	8700 µS/cm	-
Temperature (ºC)	32.4	32.6	32.3	-
Phosphate (mg/l)	1.52	0.21	0.22	< 500
Sulphate (mg/l)	26.4	14.3	13.2	
Nitrate (mg/l)	25.27	22.2	21.3	< 20
Chloride (mg/l)	723	454	397	< 600
Lead (mg/l)	1.23	0.02	0.03	< 1
Calcium (mg/l)	40	39	40	< 1
Copper (mg/l)	2.43	0.02	0.02	
Iron (mg/l)	6.34	15.12	16.63	< 20.0
Manganese (mg/l)	4.81	0.02	0.04	< 0.50
Mecury (mg/l)	1.6	0.01	0.01	
Cadmium (mg/l)	0.23	0.01	0.01	
Nickel (mg/l)	0.32	0.01	0.02	< 1
Zinc (mg/l)	6.14	5.12	5.03	< 1

Table 4: Composition of leachate collected at 5 m from the mid-section of Oluku, Uselu and New Benin dumpsites

Parameters	Oluku	Uselu	New Benin	FEPA Standard
pH	7.2	7.1	7.1	6.8-7.2
Electrical conductivity	8250 µS/cm	8100 µS/cm	8100 µS/cm	-
Temperature (ºC)	32.4	32.6	32.3	-
Phosphate (mg/l)	1.42	0.06	0.04	< 500
Sulphate (mg/l)	25.7	13.6	12.4	
Nitrate (mg/l)	9.2	6.5	7.6	< 20
Chloride (mg/l)	184	216	223	< 600
Lead (mg/l)	-	-	-	< 1
Calcium (mg/l)	30	33	35	1
Copper (mg/l)	0.64	-	-	
Iron (mg/l)	2.34	1.12	3.63	< 20.0
Manganese (mg/l)	0.48	-	-	< 0.50
Mercury (mg/l)	-	-	-	
Cadmium (mg/l)	-	-	-	
Nickel (mg/l)	-	-	-	< 1
Zinc (mg/l)	4.91	4.12	3.81	< 1

Calcium was observed in the range of 39-44 mg/l, 39-40 mg/l and 30-35 mg/l in leachate samples collected at the mid-section, 2 m and 5 m of the three dumpsites. This range exceeded the FEPA Standard of <1 mg/l, indicating the danger of water hardness if percolated into ground water and correlates with the values of Usman *et al*. (2016). This implies that forming lather with soap will be difficult for domestic users, thereby increasing the quantity of soap required for domestic chores (Akinbile, 2006). Iron was observed in the range of 6.34-27.2 mg/l, 6.34-16.63 mg/l and 1.12-3.63 mg/l in leachate samples collected at the mid-section, 2 m and 5 m of the three dumpsites. This range exceeded the FEPA Standard of 20 mg/l. However, the WHO (2004) report indicated that a range of values from 1-3 mg/l is permissible for iron content in drinking water. It was also reported that the formation of blue baby syndrome in toddlers and goitre in adults are the consequence of consumption of water containing iron above the specified quantity (Akinbile 2006; Shyamala *et al.* 2008). Manganese was observed in the range of 0.32-13.6 mg/l, 0.02-4.81 mg/l and 0.0-0.48 mg/l in leachate samples collected at the mid-section, 2 m and 5 m of the three dumpsites. Concentration of manganese below FEPA Standard of 0.50 mg/l were found in leachate samples collected from 2m and 5m in the three dumpsites but concentrations above this standard were observed in leachate samples collected at the mid-section and 2m of Oluku dumpsite except for sample collected at 5m from the mid-section of the dumpsite which had concentration of 0.48mg/l. According to Longe and Balogun (2009), excessive dissolved iron and manganese concentrations can result in sour taste and precipitation problems raising public health risk. Lead, mercury and cadmium were found in higher and lower quantities in leachate samples collected from the mid-section and 2m from the mid-section of the three dumpsites, but no trace of these three heavy metals were detected in leachate samples collected at 5m from the mid-section of the three dumpsites. Despite the non-availability of required values specified in the FEPA Standard for accepted level of drinking water, Lead, mercury and cadmium are heavy metals found in hazardous waste such as battery and chemicals and must not in any way be detected in ground or surface water due to the cancer and cardiovascular health related risk they pose on humans. High levels of sulphates could lead to dehydration and diarrhoea, and children are more sensitive to it than adults. As observed by Siva and Prasada (2016), leachate have high concentration of heavy metals which can alter the properties and fertility of soil, thereby compromising the integrity of the soil. The high concentrations of these heavy metals being non-residual fractions in the soil can leach into soil profile and further transported to the surroundings particular ground and surface water as observed by Nwaka *et al.* (2018). Waste generation is inevitable as it is one of the products of human activities; however, the indiscriminate disposal of waste is a threat to the environment, public health and economic activities as observed in this study. The findings in this study have also revealed that leachate which is formed from the decomposition of organic matter in dumpsites mixes with water and other inorganic and toxic waste materials, thereby causing considerable change in soil properties and water quality in MSW dumping sites.

Conclusion: This study has shown that uncontrolled and untreated solid waste can result in environmental pollution and severe health risk. Also, the high toxicity level of organic compounds and heavy metals present in leachate samples tested in this study has a huge potential of surface and ground water contamination as well as compromising plant growth. Hence, it is important for waste management agencies to create public awareness of the dangers associated with open dumping of MSW as well as enacting stringent laws and policies, in order to proffer sustainable environmental solutions for the wellbeing of Nigerian residents.

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