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Comparative study of Leachate Characterization: Implication for Sustainable Environmental Management

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ABSTRACT

Understanding the sources of environmental stressors, the role of geology, climate, and technology would provide a guide to solving the problems posed by such stressors. The study examines the sources and characterization of wastes at Ikhueniro open dumpsite in Benin City, Nigeria. This will assist in the adequate design of a managerial scheme to tackle the menace posed by leachate on geoenvironment while considering the role of geology, climate, and technology. The key objectives are to carry out field study, characterize wastes in the dumpsite, and collect raw leachate emanating from the wastes heap to determine its chemistry with established scientific techniques. The results obtained show a pH value of 7.7, BOD_5/COD of 0.66 mg/L, and ammonia value of 64 mg/L; these indicate that the dumpsite is young. Furthermore, the value of 3500 mg/L COD obtained in the study indicates that the leachate cannot be discharged into the environment unless treated. By comparison with previous studies, it was observed that climate, geology, and technology are some key factors influencing the prevalence of leachate in the environment. It is recommended that dumpsites should be well designed to collect raw leachate from the source and be treated before discharging into the environment. It is further recommended that improving solid waste management through grassroots education and public awareness of the consequences of environmental mismanagement through media houses and social forums as well as funding of research geared towards specific wastes management should be adopted.

1. Introduction

Leachate is a byproduct of solid wastes facilitated by rapid urbanization, the industrial revolution, a growing population and changing lifestyles (Eric, 2003; Omorogieva and Tonjoh, 2020; Tonjoh and Omorogieva, 2020). It is common in developing nations of the world particularly in the Africa continent, some parts of Asia, and Middle East nations (Agrawal et al., 2011; Merwan et al., 2013; Xaypanya et al., 2018). The content is heterogeneous, usually obtained from waste heaps in un-designed landfills, open dumpsites, or within the streets; it is produced during organic waste degradation processes and microbial activities facilitated by rainwater amongst other factors (Omorogieva and Andre-Obayanju, 2020). The mixture is environmentally hazardous, recalcitrant and a threat to public health (Chandrappa and Das, 2012; Tawari-Fufeyin, 2015; Castro-Peixoto et al., 2018). In aquatic environments it can cause acute and chronic impacts on aquatic organisms consequently destroying biodiversity, thereby reducing populations of insightful species (Omorogieva, 2016; Godwin and Oghenekohwiroro, 2016).

In terrestrial environments, leachate can migrate from its source and destroy agricultural soil and in the process, gets absorbed and accumulate in plants eaten by man (Selinus et al., 2013; Tawari-Fufeyin, 2015). It can also seep through soil media into surface and groundwater which as a result impacts the quality of drinking water (WHO, 2012; Mandakini et al., 2016). More worrisome is the abundance of leachate in every nook and cranny of major and minor streets in developing nations without precautionary measures to address the ugly situation and the detrimental effects on the geoenvironment. To provide a lasting solution to this observable threat of leachate, it is imperative to characterize solid waste and the leachate emanating from it. This will assist in understanding the sources and contents of the waste's vis a vis the chemistry of the leachate.

In characterizing leachate, the composition and the volume generated must be put into cognizance because these factors are influenced by a variety of wastes, climatic conditions, and mode of handling as well as the stage of the leachate (Unyimadu and Enekwechi, 2004; Mukherjee et al., 2015).

In Nigeria, there is virtually little or no official data relating to the harmful effects of leachate on the environment (Tawari-Fufeyin, 2015). However, the uncontrolled dumping of solid waste within and on the outskirt of cities is creating serious environmental and public health problems since the wastes contain hazardous materials like dissolved organic matter (DO), inorganic macro components, heavy metal and xenobiotic organic compound (Wreford, 1995; Manaham, 2000; Imeokparia et al., 2009; Imasuen and Omorogieva, 2013a; Omorogieva and Andre-Obayanju, 2020).

In a study carried out by Omorogieva (2018), it was reported that people living within and around dumpsite environments in Benin City were susceptible to heavy metals load due to infiltration of leachate into surrounding groundwater. In the same vein, Imasuen and Omorogieva (2013b) also reported the accumulation of some deleterious metals in food crops grown around dumpsite environments in Benin City, Nigeria. To prevent the impending danger inherent in leachate on the environment, constant monitoring of generation wastes and enhance management techniques are required to maintain safe clean surroundings which will eventually promote the attainment of an eco-friendly environment for sustainable development (Imasuen and Omorogieva, 2015; Greater Shapperton, 2018; Banch et al., 2019).

This paper is aimed at characterizing the wastes and leachate arising from Ikhueniro open dumpsite in Benin City, Nigeria; implication for sustainable environmental management. The key objectives include detailed field study and laboratory analysis of leachate as a primary byproduct of waste as well as evaluate the role of geology (soil media), climate, and technology in leachate availability; ultimately compare the results obtained with previously published papers to ascertain the role of geology and climate in the availability and mobility of leachate. The expected outcome will assist in designing leachate management techniques to promote green environments geared towards Sustainable Development Goals (SDGs).

2. Materials and Methods

2.1. Location of study

The study area falls within the coordinates of 6°17'59.72''N and 5°35'15.6''E, 6°19'29.47''N and 5°37'54.27''E in Benin City, Nigeria. The area is over and underlain by red tropical soil and the Benin Formation respectively (Fig. 1). Benin Formation is the youngest sequence in Tertiary Niger Delta Sedimentary Basin (Nwajide, 2013; Omorogieva, 2018; Edegbai et al. 2019). It has a low relief and an annual temperature of 27 °C (Ikhile, 2016; Omorogieva and Tonjoh, 2020).

2.2. Fieldwork and sample collection

Visual characterization of the wastes was carried out on-site for one week. This was done to have an in-depth knowledge of the waste's sources, content, and possible impacts. The next step was the collection of leachate samples to determine their Physico-chemical characteristics. The leachate samples were collected randomly at three points from a pool of leachate on-site. This was done based on the scope of study and no availability of a leachate collector (Shuokr et al., 2010). Leachate samples for DO and Biological Oxygen Demand (BOD_5) assessment were scooped in DO and BOD_5 bottles, respectively.

The samples were immediately transferred from point of collection in the field to the laboratory for analysis; samples were stored in a refrigerator at 4°C before analysis (Rajkumar et al., 2012). For DO measurement, 1mL of winker solution was added to keep the sample in a proper condition before analysis. The methods and steps outlined in APHA (2005), Zakaria and Aziz (2018) in analyzing water and wastewater were carefully followed. Parameters like Electrical Conductivity (EC), pH, Total Dissolved Solids (TDS) were measured in situ with an appropriate instrument. Conversely, the heavy metal like Lead (Pb), Chromium (Cr), Copper (Cu), Zinc (Zn), Cadmium (Cd), Nickel (Ni), and Fe were measured with Atomic Absorption Spectrophotometer (AAS) model 969 with air acetylene at the Central Laboratory of the Faculty of Agriculture, University of Benin, Nigeria. Other parameters measured in the leachate include trace elements like Calcium (Ca^{2+}) Magnesium (Mg^{2+}) Sodium (Na^{+}) and Potassium (K^{+}) and Cation.

2.3. Laboratory analysis of leachate

Temperature (T), pH, and EC were determined in situ in the field (Zakaria and Aziz, 2018). The temperature of the leachate was measured with the aid of a thermometer calibration between – 10 ^{0}C to 110 ^{0}C. Its reading was taken to the nearest $\pm$1 ^{0}C by dipping the thermometer into the leachate during sample collection. Hydrogen ion concentration (pH) was measured both in situ and in the laboratory for the purpose of authenticity and quality assurance of results (Kaushik et al., 2014; Omorogieva and Tonjoh, 2020; Tonjoh and Omorogieva, 2020).

It was measured in the field using an automatic pH meter, and in the laboratory by using a buffer solution 4 and 7 solutions to calibrate the pH meter; afterward, the electrode was carefully into the sample and allowed to stand until the reading becomes steady before it was recorded (Tonjoh and Omorogieva, 2020).

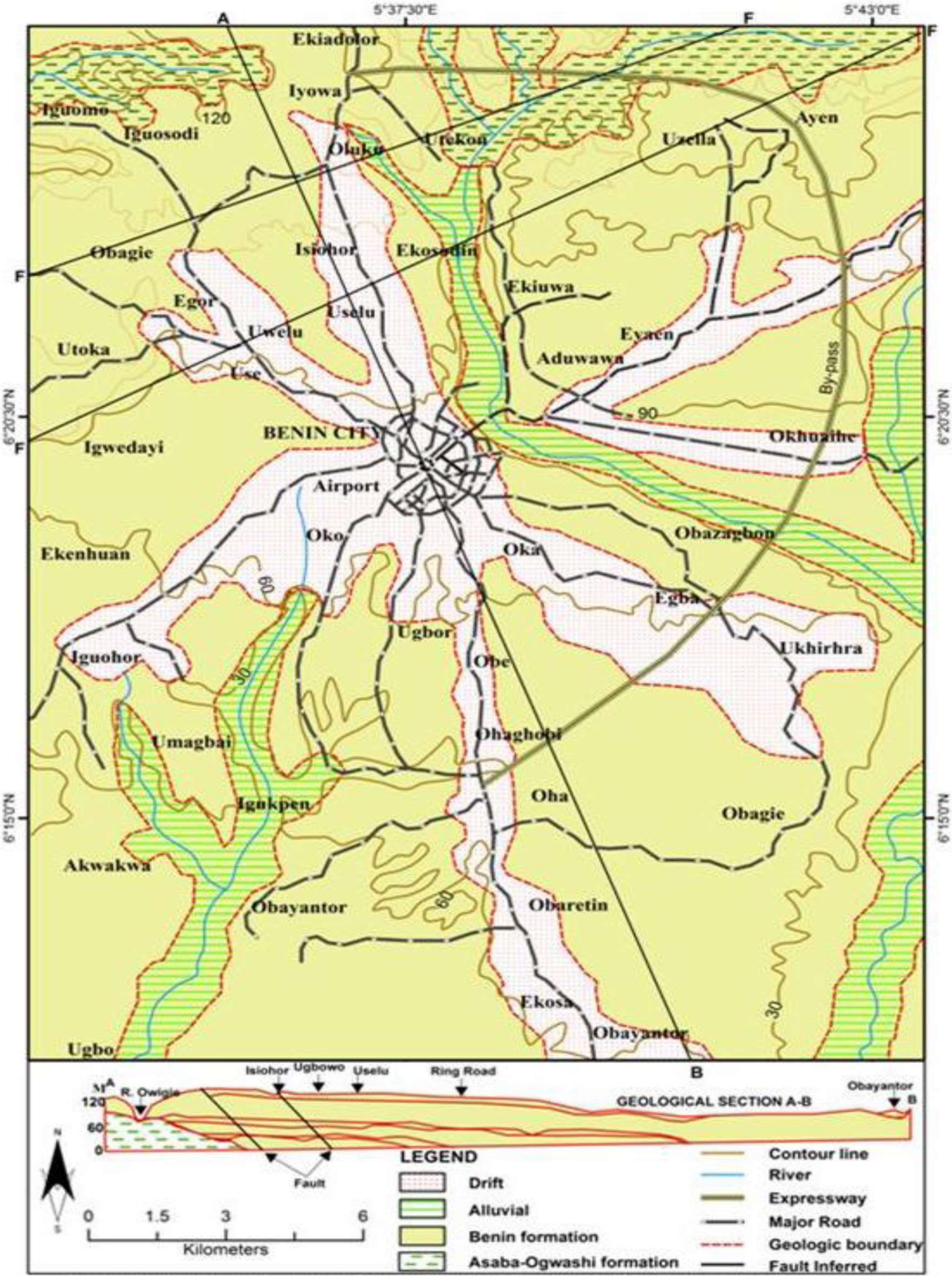

Fig. 1. Geological map guide X-section A-B of Benin City and environs extracted from Akujieze (2004)

The automatic conductivity meter (ACM) designed for in situ EC measurement was employed in field measurement and further determination in the laboratory for the precision of results generated. In the laboratory, 10 mL of the prepared sample in a 100 mL beaker and was thoroughly mixed before the reading was taken directly. For TDS, a 100 mL sample was filtered using a Whatman filter paper into an evaporating dish. The sample was heated to dryness on a water bath at a temperature of 105 ^{0}C, and the residue was properly weighed and recorded. The weight of the dish was subtracted from the final weight to obtain the weight of the TDS. About 100mL of leachate was pipetted into a filtration flask, two (2) drops of phenolphthalein indicator were added and titrated against n/50 H_2SO_4 until the pink color disappeared. Two to three drops of methyl orange indicator were added and then titrated further until the color changes from yellow to red. The whole process was repeated several times to get concordant readings. The AOAC (1984) Mohr's method was employed in chloride determination. Fifty (50 mL) of the sample was measured into a conical flask and a pinch of powdered calcium carbonate was added. This was followed by the addition of 0.1mL of Potassium dichromate as an indicator. The mixture was titrated against standard silver nitrate solution to a permanent reddish-brown precipitate.

Determination of sulfate includes measuring 10mL of the sample into a 25mL volumetric flask and distilled water was added to scale up the volume to 20mL.One (1 mL) of gelatin $BaCl_2$ was added and made up to the volume with distilled water. The content was mixed thoroughly and allowed to stand for 30minutes, to observe the color developed. The absorbance was determined at 420nm wavelength within 30minutes.A calibrated standard graph was plotted and the concentration (mg/L) of sulfate ions was obtained from the graph. Determination of Nitrate followed the **c**alorimetric method by applying an appropriate spectrophotometer. Half (0.5 mL) of each sample was used under standard (0, 2, 4, 6, 8, and 10) which was introduced into a test tube with a micropipette, and 1mL of salicylic acid ($C_7H_6O_3$) solution was added to each test tube before mixing which was allowed to stand for 30minutes. This was followed by the addition of 10 mL of sodium hydroxide to each test tube to allow the mixture for color development. The abundance of the sample and standard was read at 655nm. Determination of Total Phosphate (T.PO_4) involves the preparation of the standard solution using $(NH_4)_2$ HPO_4. 10 mL of Varnado Molybdate reagent was added with few drops of distilled water, this was mixed and diluted by the distilled water, and it was allowed to stand for 10 minutes. The absorbance of the sample solutions was determined at 470nm. Phosphates in the sample were determined from the calibration curve obtained from the standard solutions of phosphate. The BOD measures the rate of consumption of oxygen by organisms in water throughout (5) days. The BOD_5 bottle was incubated at 27 ^{0}C for 5 days in a BOD incubator, the results obtained were recorded. For Chemical Oxygen Demand (COD); a 50 mL leachate sample was pipetted into a conical flask containing 10 mL of diluted $K_2Cr_2O_7$ solution, 1mL of $HgSO_4$, and 80 mL of Ag_2SO_4– H_2SO_4 solutions respectively. A reflux greaseless condenser was fit and heated gently to boil for exactly 10 minutes; the sample was allowed to cool for some minutes. The condenser was rinsed with 50mL of water and cools under a running tap. Two drops of ferroin indicator were added and titrated with 0.025M Fe $(NH_4)_2$ $(SO_4)_2 6H_2O$ until the color changes from blue-green to red-brown. Dissolved Oxygen (DO) was determined by the Azide modification of the Winkler Method adapted for the HACH equipment from Standard Methods. The bottles were stored in dark containers underwater until their contents were titrated in the laboratory. Before titration, a powdered pillow (sulphamic acid) was added and thoroughly mixed; 20 mL aliquots were titrated with 0.200 N sodium thiosulphate using the HACH Digital titrator until the sample changed from yellow to colorless. This was achieved by the addition of a starch indicator towards the end of the experiment. The number of digits from the digital counter window multiplied by 0.1 gave the concentration of DO in mg/L. The measurements of samples were carried out in triplicates following standard practice for the examination of wastewater (APHA, 2005; Zakaria and Aziz, 2018).

3. Results and Discussion

3.1. Waste characterizations

Table 1represents waste characterization, the source, and contents based on visual assessment onsite during a one-week field exercise. The result showed that paper wastes were derived from commercial centers (market place, hotels, business, and shopping malls); institutional (Hospital, Universities, Primary and Post-Primary Schools), residential (high rising and low-cost apartment), and municipality (street trading and other activities within the municipality). Other sources consist of newsprint, combustible and recyclable materials such as unused cartons as well as non-recyclable paper wastes like garden trims. They are usually set on fire at regular intervals as a control measure of waste reduction dumped in the site. This practice introduces greenhouse gases in the ambient environment and consequently reduces visibility while raising the mortality rate through the process of respiration of air laden with carbon (II) oxide and other deleterious toxicants. Air contaminated with high doses of greenhouse gases like carbon (II) oxide, nitrous oxide (NOx), and methane (CH_4) can affect the respiratory system and other internal organs like the liver and heart as demonstrated in the work of Isley et al. (2018). None-biodegradable plastics and polythene wastes contribute the largest amount of waste stream on the site. This set of wastes contain dioxins, Polycyclic Aromatic Hydrocarbon (PAH), NO_x, heavy metals, and other greenhouse gases. Its origin is traced to commercial, residential, and institutional centers in and around the study area. It contributes significantly to the level of greenhouse gases in the atmosphere and they reduce visibility on combustion, affect respiratory systems as well as destroying the ozone layer thereby increasing global temperature leading to flooding. Global warming can alter the population of insightful species and eventually lead to loss of biota and food shortage.

Additionally, it can impede the growth of plants and reduce the size of agricultural land as a result of its non-biodegradable characteristics. Glass wastes were also recorded during the field study as represented in Table 1. The fraction consists of alcoholic and chemical bottles as well as glass containers of different types sourced from chemical producing industries, hospitals and clinics, beverages and bottling companies as well as cosmetic firms. Interestingly, broken bottles can penetrate the human body during scavenging of wastes by scavengers, in an attempt to make ends meet, and in the process, these scavengers get infected with tetanus. Chemicals are hazardous in nature; and when leached in soil, they enrich the background concentration of naturally occurring elements and other toxicants in the biosphere and hydrosphere respectively.

Table1. Classification of waste modified in Omorogieva (2018)

Group	No	Material category
Paper	1	Compostable paper
	2	Newsprint
	3	Non-recyclable paper
Metal	4	Aluminum beverage containers
	5	Ferrous food and beverage containers
	6	Other aluminum containers
	7	Other ferrous scrap metals
	8	Other non-ferrous scrap metals
Glass	9	Alcoholic bottles
	10	Chemical bottles
	11	Mix bottles
	12	Glass deposit containers
Organic	13	Yard waste
	14	Food waste
	15	Textiles and leather
	16	Wood
Plastic	17	Deposit beverage containers
	18	Polythene
	19	Vehicle tires
	20	Rubber pipes
	21	Other plastic products
Durable	22	Cell phones and chargers
	23	Central processing units/peripherals
	24	Computer monitors and televisions
	25	Electrical and household appliances
HHMs	26	Automotive products
	27	Household cleaners
	28	Lead acid batteries
	29	Paints and solvents
	30	Pesticides, herbicides, fungicides containers
	31	Sharp objects
Sewage sludge	32	Sullage and human body wastes

Consequently, surface and groundwater are contaminated especially when the aquifer in such an environment is unconfined as observed in the study of Omorogieva et al. (2016) and Omorogieva and Imasuen (2018). Metal wastes were also recorded on the list of wastes represented in Table 1. The metals include the remains of abandoned vehicles, iron scraps, aluminum beverage containers, empty cans of processed food, ferrous and non-ferrous insecticide cans, and other household materials made of metal. These fractions can undergo rusting and increase the concentration of metal load in the geoenvironment as a result. Plant roots absorb these metals in form of nutrients when dissolved in soil or are leached into groundwater. Groundwater containing a high amount of iron can cause a disease condition known as hemochromatosis when consumed in large quantities (Searle et al. 2001; Selinus et al. 2003).

Organic wastes were also accounted for during the field study (Table 1). They include food waste, poultry droppings, textile, leather, and wood wastes as well as sewage sludge (sullage and human body wastes) which have been reported as the main source of chlorine, heavy metals, and nitrous oxides in groundwater (Manahan, 2010).

Organic wastes like food waste and poultry droppings can be applied as soil conditioners to boost agricultural yield, whereas others like hiding and skin, sewage sludge can be recalcitrant in the environment if not well disposed of. Sewage sludge is a source of heavy metals, responsible for low DO, coliform, and e-coli counts, and a host of other water quality parameters which are deleterious to public health. Durables which consist of electronics waste (e-waste) such as cell phones, battery chargers, computer and televisions parts, electrical and household appliances were not left out in the study. E-waste is currently one of the main causes of failing health (Idehai, 2013). Hazardous Household Materials (HHMs) were also on the list of wastes recorded in the study. It consists of household cleaners, lead-acid batteries, paints and solvents, pesticides, herbicides, fungicides containers, sharp objects, spent oil, and automotive products. The content can enrich the background values of the elemental content of the geosphere and they can cause hazards to the environment as well as public health because they are explosive, corrosive, and are highly flammable (Manahan, 2010).

Table 2 represents leachate characterization in comparison to previous studies in Ojota, Lagos, Nigeria; Dusseldorf in Germany; Alor Pongsu in Malaysia; Indonesia, Thailand, and Pitsea, United Kingdom. This was to understand the role of climate and geology in the availability, and chemistry of leachate. From the result recorded in the current study, it was observed that ammonia and nitrate levels in the leachate were low with values of 64 mg l^{-1} and 4.2 mg l^{-1} respectively. The pH value of 7.7 recorded indicates neutral to alkaline while the BOD_5/COD ratio stands at 0.66 mg l^{-1}. These values recorded are a reflection of the decrease in volatile fatty acid leading to an increase in pH and alkalinity values. These parameters are used to calculate the stage in the life cycle of a typical dumpsite.

According to Kurniawa et al. (2006), there are three stages of leachate; young leachate > 0.5, intermediate leachate 0.1 – 0.5, and < 0.1 which is regarded as a stabilized leachate. In comparing the value of the BOD_5/COD ratio of the current study with previous studies, it was observed that Malaysia leachate with BOD_5/COD ratio of 0.05 was classified as a stabilized leachate whereas Düsseldorf in Germany, Pitsea in the United Kingdom and Indonesia with BOD_5/COD ratio of 0.36, 0.15 and 0.32 respectively were classified as intermediate leachate. On the other hand, Thailand (0.97), Ikhueniro in Benin City, Nigeria (0.66), and Ojota in Lagos, Nigeria (0.53) was classified as young leachate meaning that the process of stabilization is ongoing (Fig. 2).

The high concentration of 3500mg/L COD value obtained in this study indicates that the leachate cannot be discharged into the ambient environment because of the high risk of geoenvironment contamination. COD is usually used to test for the strength of pollutants contained in a sample; COD values greater than 400 mg/L should not be discharged into the environment (Zakaria and Aziz, 2018).

Additionally, COD in a sample can be used to measure the age of a dumpsite or a landfill site because, at an early stage of a dumpsite, the value of COD is usually high and decrease in concentration with time. As an environmental pollution indicator, COD can be used to interpret the condition of solvents and their impact on the surrounding environment. When the concentration of COD in leachate is high, it means that such leachate or solution cannot be discharged in the environment. It is, therefore, necessary to measure the COD in wastewater or leachate to help manage the environment. For the classification of the stages of the dumpsite, the value of 3500 mg/L COD measured in the current study indicated that the dumpsite is in a methanogenic or stabilized phase having value ranges of 500-5000 mg/L (Kulikowska and Klimiuk, 2008).

Table 2 summary of the physico-chemical result obtained for leachate in the study areas (modify after Unyimadu and Enekwechi (2004))

Parameters	Leachate Ikhueniro	Ojota Lagos	Dusseldorf Germany	Pitsea United Kingdom	Malaysia	Indonesia	Thailand	WHO (2011)	SON (2015)
Temperature (^{0}C)	30	-	-	-	29.8			20	20
pH	7.70	7.40	8.00	8.0-8.50	8.13	7.42-7.45	8.00	6.9	6.5
EC (uS/cm)	1557	10000	17000	-	-	-	-	1200	1000
TDS (mgl^{-1})	550	5000	8500	-	6237	1.2-1.26	18900	250	250
TOC (mgl^{-1})	1250	-	-	200-650	-	-	-	NA	NA
TSS (mgl^{-1})	640	500	-	100-200	-	-	-	500	1500
COD (mgl^{-1})	3500	1602	3900	850-1350	3852	291.1-588	4300	NA	NA
BOD_5 (mgl^{-1})	2300	850	1400	80-250	196	62-218.10	418	NA	NA
BOD_5/COD	0.66	0.53	0.36	0.15	0.05	0.32	0.97	NA	
NH_3 (mgl^{-1})	64	150	1066	200-600	-	-	-	NA	NA
NH_3–N	-	-	-	-	1241	62-125	1934	-	-
NO_2^- (mgl^{-1})	4.2	2.5	-	5-10	-	-	-	0.2	3
NO_3^- (mgl^{-1})	25	0.2	-	0.1-10	-	-	-	50	10
T.PO_4 (mgl^{-1})	105	3.5	-	0.20	-	-	-	20	0.2
Cl^{2-} (mgl^{-1})	860	1000	2200	-	-	-	-	250	100
SO_4^{2-} (mgl^{-1})	700	25	-	-	-	-	-	500	100
Mg^{2+} (mgl^{-1})	440	540	210	-	-	-	-	20	0.2
Ca^{2+} (mgl^{-1})	605	1460	190	-	-	-	-	NS	75
Pb (mgl^{-1})	6.46	0.0113	0.10	-	-	-	-	0.01	0.01
Cr (mgl^{-1})	4.11	ND	0.6	-	-	-	-	0.05	0.05
Cu (mgl^{-1})	22.56	ND	0.08	-	-	-	-	2	1
Zn (mgl^{-1})	18.7	ND	0.40	-	-	-	-	3	5
Cd (mgl^{-1})	5.02	ND	0.007	-	-	-	-	0.003	0.003
Ni (mgl^{-1})	4.15	-	0.27	-	-	-	-	NA	0.02
Fe (mgl^{-1})	500	1.06	-	-	-	-	-	0.3	0.3
Alkalinity (mgl^{-1})	660	-	-	-	-	-	-	100	100
Hardness (mgl^{-1})	622	-	-	-	-	-	-	500	100
DO (mgl^{-1})	10.8	-	-	-	0.85	-	-	NA	NA
HCO_3^- (mgl^{-1})	2000	-	-	-	-	-	-	NA	NA
K^+ (mgl^{-1})	200	-	-	-	-	-	-	NA	10
Na^+ (mgl^{-1})	400	-	-	-	-	-	-	NA	NA
CO_3^- (mgl^{-1})	550	-	-	-	-	-	-	NA	NA

NA = Not available

Although the value of 2300 mg l^{-1} BOD_5obtained in the current study is higher than 200 mgl^{-1} BOD_5 characteristics of a stabilized landfill (Unyimadu and Enekwechi (2004), but the average data values conformed with a stabilized phase as compared to previous studies in Dusseldorf Germany (1400 mg/L), Pitsea United Kingdom (250 mg/L), Pongsu in Malaysia (196 mg/L), Thailand (418 mg/L) and Ojota, Nigeria (850 mg/L). In environmental monitoring, BOD_5 value ranging between 100 - 200 mg/L is said to be in its advanced stage with an average age less than (≤) 10 years whereas leachate from dumpsite with an average BOD_5 greater than (≥) 200 mg/L could be classified as young dumpsite (Zakaria and Aziz, 2018). The high value of BOD_5 in the current study compared to previous studies is attributed to the environmental and climatic conditions of the area of study which is characterized with coarse sand, moderately sorted, and allows easy flow of water (Ilevbare, 2019); this is further facilitated by heavy rainfall, high temperature, and poor technological knowhow. The presence of water, nature of the waste composition, temperature, age of dumpsite, available oxygen, and toxicity are some of the factors that facilitate and influence the production and characteristics of leachate. At the early stage of leachate formation, BOD_5, COD, pH is usually very high but decreases with time (Adhikari et al. 2014; Dawood et al. 2017; Xaypanya et al. 2018).

Because leachate is highly variable and a distinctly heterogeneous substance; these factors interact and may vary considerably even in a relatively short term, and more so, over a decade of a typical dumpsite and throughout the lifetime of a landfill (Cope, 1995). Furthermore, a high chloride value of 860 mg l^{-1} and sulfate of 700 mg l^{-1} above (WHO, 2011) maximum desirable limit of 100 mg l^{-1} as well as the Standard Organization of Nigeria (SON, 2015) could be traced to the sewage sludge being dumped in the site.

The mobility and concentration are enhanced by the geology of the study site which is described as the Benin Formation. The soil characteristics of the area allow materials to percolate through it especially when there is water to facilitate mobility. Since the dumpsite lacks engineering properties to consider it as a landfill, incessant dumping of sewage and other waste products in such a dumpsite coupled with heavy rainfall and the geology of the terrain will give room for deleterious substances like heavy metal, dioxins, organic and inorganic toxicants as well as xenophobic materials contained in leachate to seep through porous soil media into the shallow aquifer which may eventually impact the quality of groundwater in the environment.

Other parameters measured in the study include total phosphate (T.PO_4^{2-}) 105 mg l^{-1} DO of 10.8 mg l^{-1}, TDS 550 mg l^{-1}, EC 1557 uS/cm, and total suspended solids (TSS) 640 mg l^{-1} were significantly high indicating a potential risk when discharged into the environment without necessary treatment (Noerfitriyan et al., 2018). It was observed that the value of 10.0 mg/l DO measure in the current study is higher than 0.85 mg/l measured in the previous study carried out in Malaysia while the TDS value of 550 mg/l measured in the current study was lower than the mean value of 6237 mg/l compared to previous studies (Table 2).

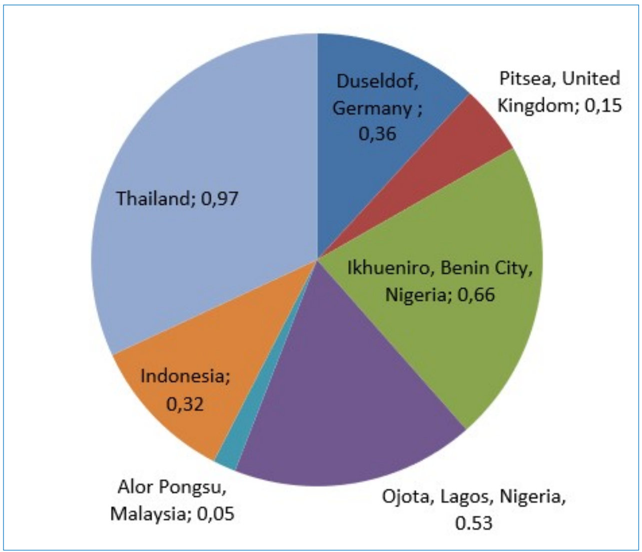

Fig. 2. Comparison of BOD_5/COD ratio (mg/L) of Ikhueniro, Benin City, Nigeria to previous studies

The variation in results obtained across the studies is attributed to climatic conditions, geology (soil type), time, and technological inputs in terms of site design. It is imperative to state that waste generated is directly proportional to the prevailing population and the composition of waste materials; in other words, climatic conditions determine the amount of rainfall and temperature condition of an area which in turn determines the characteristics of the leachate generated (Longe and Balogu, 2010; Soujanya, 2016). Aquifers that are capped with thick sedimentary beds like clay would be protected due to the impermeable nature of clay rock, and as absorbent material for heavy metals. However, if the geological material overlying an aquifer is porous and permeable like unconsolidated sands, sandstone, and fractured basement rocks, there would be a high probability of the underlying aquifer being vulnerable to contamination (Mandishona et al. 1995; Onyeobi and Akujieze, 2014; Omorogieva and Imasuen, 2018).

Leachate movement might also be restricted by climatic conditions and local geology in an area because high temperature can dry up available leachate whereas rock strata like clay can trap the contaminants contained in leachate as well as restrict the movement of the leachate. Consequently, water bodies may be protected if not exposed to other geoenvironmental contaminants like open defecation, septic tank leakage, oil spill, natural disaster, and direct discharge of wastewater from abattoir and industries. Aside from groundwater contamination, discharging untreated leachate and wastewater into the environment could be very dangerous because plant roots and fishes in the aquatic environment can absorb deleterious contaminants contained in leachate that may be subsequently consumed by man through the food chain (SON, 2015)

4. Conclusion

Municipal Solid Waste (MSW) being the main source of leachate needs to be characterized to determine its source and contents. The results obtained in the study show that the contents of the leachate characterized are potentially toxic to the environment and human health if not properly treated. The values of ammonia, pH and BOD5/COD ratio recorded in the study indicate that the leachate is young while the dumpsite is in its methanogenic stage. Understanding the composition and chemistry of leachate as well as the geology and climatic conditions of an area will assist in designing an adequate managerial scheme in collecting and treating leachate before discharging into the environment. In doing so, the hazards caused by untreated leachate in the environment will be highly minimized. The geology and climatic conditions of an area play a significant role in the mobility and availability of leachate in an environment, and the chemistry of the leachate will determine whether or not it can be discharged directly into the environment. Based on the findings, it is strongly recommended that improving solid waste management through a private-public partnership, grassroots wastes management education, public awareness through media houses like radio, television, newsprint, social media, conversion of organic wastes into soil conditioner and energy as well as funding of research geared towards specific wastes management will help to reduce groundwater and environmental contamination caused by leachate arising from the solid waste heap.

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Conflict of Interest

There is no conflict of interest in this study.

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