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Profiling and Characterization of Environmental Quality of Leachates from Selected Dumpsites in Owerri, Imo State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study profiled and characterized environmental quality of selected dumpsite leachates in Imo State with emphasis on Nekede, Worldbank, Irete and Orji areas of the state. Leachates were collected under stringent sample collection protocols from the selected dumpsites and analyzed. Samples were collected from three different sampling points of the dumpsite and bulked to form representative sample for each sampling site. The samples were analyzed for a number of standard physical and chemical parameters using standard analytical protocols and compared with the Federal Ministry of Environment (FMENV) benchmark. The result of the analysis showed that the values of electrical conductivity, total dissolved solid, temperature, BOD, COD, CO, salinity, sulphate, chloride, turbidity, nickel, chromium, lead, and cadmium were above FMENV limit; while nitrate, sulphate and zinc (from Worldbank, Irete and Orji), were below FMENV detectable limit. The outcome of the study is a pointer to the fact that the assayed leachates have high pollution potentials. There is possibility of gradual buildup of contaminants in the study area's dumpsites,

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which could pose a serious threat, including the inhabitants around the vicinity. The study underscores the need for continual monitoring of the dumpsite leachates, and possibly an upgrade to a sustainable engineered landfill, to forestall possible pollution problems of other components of the environment such as aquatic bodies in future.

Keywords: Leachates; quality; pollution; Owerri; Imo State; FMENV.

1. INTRODUCTION

Waste generation is an indispensable aspect of human endeavor. This is because almost every activity by man generates wastes of some kind [1]. In most developing countries, the propensity of residents to generate waste seems to have heightened in recent times [2]. This has been largely ascribed to accelerated industrialization, urbanization, and population growth; which have elicited strong international and national concerns about the possible environmental, health and safety effects of living in the vicinity of these wastes [3],[4]. Landfilling and or open dumping of wastes are very common methods of managing these wastes [5],[6]. This is because it is the cheapest and most convenient way of disposing municipal solid wastes. However, all efforts to get rid of waste also pollute the environment to some extent [4], [7].

Solid waste management has been a major problem in the world especially in most developing countries [8]. The problem is exacerbated by the lack of well-organized waste management strategy [1];[2]. Most major cities have no functional waste management system. Traditionally, most domestic and industrial wastes are disposed directly either into open dump sites which are often subjected to open incineration or into gutter drains, rivers and swamps [8]. The increasing volume of municipal solid waste in Nigeria including Imo State, reflect the dramatic population growth, and its shift from rural areas to urban sector [9]. This increase in waste generation has also increased the challenge of how to get rid of it without causing undesirable impact on the environment and subsequently on public health [10-13].

The accumulation of waste disposed in landfills could result in generation of a liquid waste water product known as leachate. Leachate is a widely used term in the environmental sciences where it has the specific meaning of a liquid that has dissolved or entrained environmentally harmful substance that may then enter the environment [14]. It is most commonly used in the context of landfill of putrescible or industrial waste [15]. However, in the narrow environmental context, leachate is liquid material that drains from land or stockpiled material and may contain significantly elevated concentration of undesirable materials derived from materials that it has passed through [11], [14]. When water percolates through waste, it promotes and assists the process of decomposition by bacteria and fungi. This process in turn release by-products of decomposition and rapidly use up any available oxygen, creating an anoxic environment [16].

Landfill leachate may be characterized as water-based solution of four groups of contaminants; dissolved organic matter (alcohol, acid, aldehydes, short chain sugar etc.), inorganic macro component (common cation and anions including sulfate, chloride, iron, aluminum, zinc and ammonia), heavy metals (Pb, Ni, Cu, Hg), and xenobiotic organic compound such as halogenated organics (PCBs, dioxins, etc.) [17]. The presence of humic substance in leachate might enhance the transportation of heavy metals in addition to the increase of ash content in landfill [11]. In a study to characterize the landfill leachates in central Taiwan, Huan-jung *et al*. (2006) analyzed the liquid output of three types of landfills, they pointed out that the active landfill leachates had high concentrations of the COD, volatile suspended solids, TDS, total organic carbon (TOC), electrical conductivity and had high contents of Fe, Cr and Ni. The contamination of the natural environment from pollutants leaching from this dumpsite constitutes very serious problem because most landfill leachates contain a high concentration of organic matters and inorganic ions, including heavy metals [18].

There are sufficient evidences from the literature that the landfill leachates may cause a serious environmental problem by discharging heavy metals continuously, if it is not put under control [19-21]. Several works have been done on different dumpsites in many parts of the world, and also, in Nigeria that show how the quality of groundwater and human health is affected by leachate percolation into underground water bodies [22-24].

As opined by [20], the environment can be polluted by leachates from dumpsites which occur at the end of the decay of solid waste, mixed with precipitates of surface water. As a result, surface water collection system (rivers, creeks, and lakes), subsurface collection system (groundwater reservoirs) and solid system (different soil layers) become vulnerable to pollution from the dumpsite. A number of incidences have been reported in the past where leachates have contaminated the surrounding soil and polluted the underlying groundwater aquifer or nearby surface water [16];[18].

The crux of this study therefore, was to profile and characterize dumpsite leachates from Nekede, Orji, Irete, and Worldbank in other to appraise their characteristics and possible impact on the environmental quality of the study areas. The data obtained in this study can help to prioritize sustainable management of landfills for reducing the risk associated with these landfills in the environment.

2. MATERIALS AND METHODS

Four different sites (Nekede, Orji, Irete, and Worldbank) located in Owerri zone of Imo State were pre-selected for sample collection. Glass bottles were used to collect dumpsite leachate for chemical analysis, whereas, samples for BOD_5 and COD tests were collected in polyethylene bottles covered with aluminum foils. Samples were collected from three sampling points, bulked together to form composite. In order to avoid chemical and biological changes that have the ability to change the natural state of the samples, a few drops (1ml) of concentrated HNO_3 was added to the sample meant for heavy metals analysis and 2ml concentrated H_2SO_4 added to samples for COD analysis to make the pH equal 2.0. The samples were then transported in a cool box and stored under suitable temperature until analysis. Prior to leachate sample collection, the containers were rinsed with the samples in order to avoid contamination from externalities and acclimatize the containers to the sample environment. Twenty-two (22) parameters were measured using Atomic Absorption Spectrometer (AAS) for heavy metals.

3. RESULTS AND DISCUSSION

Leachate evaluation outcomes are presented in Table 1. A total of 22 parameters, including 7 metals were measured. In the landfill leachate, all were detected except for TPH, PAH and Ni.

The impact of leachate on groundwater and other water resources has attracted a lot of care because of its devastating environmental significance. Leachate pH value of 7.86-8.08 (Table 1) indicates slightly alkaline status of the water and could enhance methanogenic process.[24], [22] and [5] reported range of 7.0-8.0,7.0-7.8 and 7.74-8.17 respectively, which aligns with present study. [25-29] documented lower pH values of 6.78-6.93 while [11] reported 5.10-8.60. In this study, pH results highlight short acidic phase and early methanogenic phase [9]. A study by [13] for a landfill leachate in Malaysia reported degradation at late acidic phase as pH averaged 6.7. The leachate pH increases as landfill ages [19]. Addition of acid or alkali from waste could alter the leachate characteristics and could aid metal solubility and consequent elevation of their concentration and toxicity potential [30].

BOD and COD values obtained in present result contrast with studies by [14] who got 296 mg/l and 3340 mg/L [27] with values 5000 mg/L and 20 mg/L, [15] -1000mg/L and 60 mg/L, Hassan and Ramadan (2005) who documented 28,833mg/l and 45,240 mg/L in Malaysia and Abd El-Salam and Abu-Zuid(2015), who studied landfill leachate in Egypt with value 10,824 mg/l and 15,629 mg/l. Significant variations exist in many factors including chemical composition [31] however the ratio of BOD to COD, considered as a good indicator of the proportion of biochemically degradable organic matter to total organic matter [21] for the present study is 0.58, 0.65, 0.63 and 0.71 for Nekede dumpsite, World Bank MLS, Irete MLS and Orji MLS correspondingly. This is in tandem with [32-35] and [36], with values 0.58, 0.63 and 0.69 respectively. The ratio indicates high biodegradable leachate around acid phase of anaerobic degradation [5]. Age of landfill is considered a factor in the pollution strength of landfill leachate as young leachate are more polluting than matured leachate with BOD potential reaching 80,000 mg/L while old landfill reaches 4200 mg/L [5]. The present study low BOD and COD values could be due to inconsistency in waste type and characteristics, non-shredding of waste prior to disposal, low density due to non-compaction that reduced degradation and meteorological condition such as temperature and pressure in the dumpsite [5].

The conductivity concentration of 11,300 µS/cm at Nekede dumpsite was highest compared to the three MLS sampled, though with Irete MLS concentration similar to the Nekede concentration- about 94%. The values are higher than FEPA and WHO permissible limit. It is higher than concentration obtained by [33] of range 4116-5592 µS/cm. [32] reported an upper limit of 12,500 µS/cm at Awotan dumpsite in Southwest Nigeria. Leachate concentration is described as an indication of elevated amounts of pollutants [33]. Table 1 showcase a generation indication of higher concentration of measured elements on the Nekede dumpsite and the Irete MLS against the World Bank and Orji MLS. Investigation indicates Irete dumpsite has not been evacuated for a long time which seems to align it with a final disposal site, while the dirt at World Bank and Orji stations are evacuated and hauled to the Nekede dumpsite at least once a week, hence lower concentration of contaminants as Table 1 portrays. The implication is that a high amount of dissolved organic matters with potential of provision of adsorptive sites for some form of biological and chemical agents could cause pollution of underground water, nearby soil and even vegetation around the dumpsite surrounding [33]. [37] and [33] have reported this trend. According to [38] leachates are formed when water (generally rainwater) percolates through the dumped waste and takes up the organic and inorganic products from both physical extraction, hydrolytic and fermentative processes. It is a good indicator of its salinity or total salt content [33]. According to [38], leachate generally contain high concentrations of soluble organic matter and inorganic ions. [39] and [33] conclude that landfill leachates could alter aquatic ecosystem if it finds its way into the river which could lead to propagation of anaerobic biota and consequent enhancement of anoxic conditions in the river.

The TDS level of 5663 mg/L was close to upper limit of 5180 mg/L reported by [33] and much higher than average amount of 1061.25 mg/L and range of 29.8-42.1 mg/L reported by [32] and [29] respectively. The value of the study is more than WHO (2004) and SON (2007) permissible limit of 1000 mg/L and 500 mg/L, and indicative of high mineralisation. [12] concluded that the presence of inorganic salts such as potassium, chloride, calcium, magnesium, sulphate and bicarbonate could be signified by high concentration of TDS.

The nitrate and sulphate concentration were within recommended limit, while the phosphate level of 17.15 mg/L was above FMENV limit of 5 mg/L. Burning of waste could enhance the amount of nitrate and phosphate in dumpsites [33]. There is periodic burning of waste at the Nekede dumpsite.

The turbidity levels of the leachate - 210 NTU was more than range of 62.21-86.11 NTU and 5-25 NTU reported by [33] and [37] respectively. The value was above WHO limit of 5 NTU. [37] concludes that discharge of increasing amount of highly turbid leachate could cause toxic status of the water to increase. [30] asserts that though there are no serious health implication of turbidity, but it could interfere with disinfection and provide a sterile environment for microbial growth. High turbidity could be as a result of Municipal run-off of soil and inorganic particulate matter disturbance from weathering of rocks [30].

Heavy metal concentration among the Nekede dumpsite and the selected transfer locations as displayed in Table 1, point towards same dynamics as earlier discussed. Concentration of parameters investigated trend as follows: Fe>Cr>Zn>Cu>Pb>Ni>Cd. Result indicates that Cr and Fe are well above regulatory limit which could be of pollution effect through runoff into surface water or by percolation into groundwater. [9] reported similar trend.

Chromium (Cr) exists in solid or mineral type and more minute than the other elements, with its natural source being rock mineral erosion which mainly settles in sediments, while the anthropogenic source could be from burning process which finally sink to water surface by precipitation as well as discharge from households' waste and industries [27].Chromium releases in the environment are in hexavalent form, ie Cr(VI) and could pose a carcinogenic risk [25].

It is obvious that leachate from dumpsites could be of high pollution effect as it poses varied contamination effect including high risk to groundwater resources if not properly managed [39].

So, with leachate run off into the rivers, the water purification of rivers could be impacted. Moreover, accumulation of other trace metals such as copper, lead and zinc could be detrimental to the water bodies. Lead could be from paint, pesticides, batteries, automobile

Table 1. Leachate from Nekede dumpsite and selected key waste transfer points

Location	Nekede dumpsite	World Bank MLS	Irete MLS	Orji MLS	FMENV Limit
GPS Location	N05.46405 E07.03067	N05.48174 E07.00232	N05.51396 N06.98996	N05.53449 E07.06309	
Parameter					
pH	8.08	7.93	8.01	7.86	6.5 – 8.5
Temperature (^{0}C)	30.41	29.54	28.82	29.00	35
BOD_5 (mg/L)	25.21	34.08	39.10	17.12	10
COD (mg/L)	43.37	52.27	62.14	24.20	40
DO (mg/L)	0.65	1.83	0.38	2.26	-
TSS (mg/L)	115.00	45.31	109.37	35.83	30
Conductivity (µS/cm)	11300	805	10,633	2083	-
TDS (mg/L))	5663	398	4983	1002	2000
Salinity (mg/L)	650	186	605	435	600
Turbidity (NTU)	210	53	243	115	-
TPH (mg/L)	<0.01	<0.01	<0.01	<0.01	-
PAHs (mg/L)	<0.01	<0.01	0.02	<0.01	-
Nitrate (mg/L)	8.57	1.08	1.83	0.56	20
Phosphate (mg/L)	17.15	2.22	3.16	0.34	5
Sulphate (mg/L)	3.15	1.13	2.05	0.15	500
Lead (mg/L)	0.02	<0.01	0.02	<0.01	0.05
Iron (mg/L)	1.49	0.12	0.84	<0.01	-
Zinc (mg/L)	0.220	<0.01	0.30	<0.01	1.0
Nickel (mg/L)	<0.01	<0.01	<0.01	<0.01	
Cadmium (mg/L)	0.11	<0.01	0.08	<0.01	0.5
Chromium (mg/L)	0.24	<0.01	0.12	<0.01	0.10
Copper (mg/L)	0.31	<0.01	0.14	<0.01	1.5

emissions [16]. Effect from point and non-point sources such as gasoline, municipal run offs and atmospheric deposition could be source of lead [35]; [9]; [28]. Activities around the site is heavily domiciled by heavy duty trucks that come to drop waste in dumpsite or haulage of sand due to dredging operations around there. Meanwhile hawking of automated gas oil around the site is prominent with eminent spill during transfer and fueling of trucks, payloaders and dredgers.

The high concentration of iron above all metals as earlier stated may be connected with the reported high Fe level in the Southern Nigeria upper earth crust [9];[23]; [18]. The leachate collection point is less than 100 meters to the dredging strip which could have impact on the structural integrity of the dredged materials. Ground water average flow rate is estimated at 400 m/year and the leachate could move away from its source at same rate [4], [3]. So, in 5 years, the leachate would have transversed about 2km. This could indicate future potential pollution.

4. CONCLUSION

The characteristics of leachates dumpsites from Orji, Worldbank, Irete and Nekede were profiled in this study. The result of the analysis showed that the analyzed parameters were above FMENV permissible limit except nitrate, sulphate (from Worldbank, Irete and Orji MLS), and zinc which were below FMENV detectable limit. The result revealed that the assayed dumpsite leachates have high pollution potentials. There is possibility of gradual buildup of the contaminants in these dumpsites leachates which could pose a serious threat to the inhabitants around the vicinity if nothing is done to remedy the current situation. We recommend continual monitoring of the dumpsite leachates and sustainable remediation technology, to forestall possible pollution problems of other components of the ecosystem such as aquatic bodies in the future.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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