Asian Journal of Geological Research

3(1): 35-44, 2020; Article no.AJOGER.54596

Impacts of Solid Waste Dumpsites Leachate on Groundwater Quality and Suggested Mitigation Measures by Targeting Specific Pollutant Sources: Ikhueniro, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author OMO designed the research in consultation with authors OMO and OAO carried out the field exercise, collects samples and prepared same for analysis. Both authors wrote the protocol and the first draft of the manuscript.

Article Information

Editor(s):
(1) Dr. Ahmed Abdelraheem Frghaly, Sohag University, Egypt.
Reviewers:
(1) Col. Islam-Ul-Haque, Pakistan.
(2) M. Harish Raju, Visvesvaraya Technological University, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/54596

Original Research Article

Received 18 December 2019
Accepted 22 February 2020
Published 19 March 2020

ABSTRACT

The study of leachate is an on-going and current debate on global platform by researchers across disciplines. This is because of its impact on geoenvironment, particularly on groundwater resources. The study aimed at examining heavy metal and physico-chemical characteristics of leachate and its impacts on groundwater in Ikhueniro, Benin City Nigeria. The study findings will propose management strategies to promote environmental safety and groundwater resources protection. The study employed integrated scientific techniques and literature review to actualize its goals. The results obtained in the study revealed that the values of pH and Pb range were 5.78 – 6.80 and 0.03-0.05 mg/l respectively. Others include Fe (0.03-0.9) and Ni (0.05-0.64). It was observed that groundwater samples tested for heavy metal Pb, Cr, Cu, Zn, Cd, Ni and Fe in borehole tagged GW1, GW2, GW5 and RW within and around the study site were significantly impacted with Pb, Ni and Fe while GW2, GW5 and RW were lower in concentration of Pb, Cr, Cu, Zn, Cd, Ni and Fe. The study further revealed that leachate plume from dumpsite at the study site

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was the source of groundwater contamination. In view of the foregoing, the authors proposed that waste management techniques at grassroots level and strict compliance to the 4Rs methods of waste management practices as well as enforcement of environmental laws should be strictly adhered to in management of safe environment and protection of groundwater resources for sustainable development.

Keywords: Leachate; environment; climate; groundwater protection; environmental management.

1. INTRODUCTION

Leachate is a heterogeneous mixture of substances emanating from waste heaps, landfill and open dumpsites during organic waste degradation processes and addition of water (rain water) amongst other factors. The mixture contains hazardous substance like heavy metal, dissolved organic matter, inorganic macro components and xenobiotic organic compound [1,2]. These substances are environmental recalcitrant and public health concern [3]. Excessive leachate streams in aquatic environment have both an acute and chronic impact on the environment that is capable of destroying biodiversity and to a great extent trim down populations of insightful species. When toxic metals and organics are present in leachate, it can lead to chronic toxin accumulation in both local and far distant populations. Leachate is highly mobile and can easily infiltrate through porous soil media to contaminate groundwater or through surface processes to pollute surface water [4-6]. Leachate is prominent in the environment especially in developing countries where wastes are dumped indiscriminately [7]. Recent quest for groundwater has increased globally, particularly in towns and semi urban in Africa countries as a result of poor technological no how to recycle waste water for further usage. This phenomena has attracted researchers globally in studies like groundwater vulnerability, leachate characterization and management, environmental modelling and water quality assessment and monitoring [8-13,5] Omorogieva and Imasuen, 2018. The United Kingdom government was among the pioneer government that conducted extensive research on the potential health risk of people living within two (2) kilometer off landfill as a source of leachate in order to examine the incidence of low birth weight, congenital defects, still birth and cancer in the vicinity of 9565 landfill sites with a sample size of excess of 8 million pregnancies [14]. In a study conducted by Omorogieva [6], it was observed that leachate emanating from selected dumpsites in Benin City, Nigeria, has a direct contact with aquifer within the vicinity of the dumpsites environment. Consequently it influenced the quality of groundwater obtained from boreholes sank within and around dumpsite environment. Similarly, Omorogieva et al. [11] Unyimadu and Enekwechi [15] also observed that groundwater obtained from borehole sited within the locus of a landfill in Lagos state, a commercial and industrial city and dumpsites environment in Benin City, Nigeria respectively were impacted with heavy metal, organic and inorganic substance suspected to have leached from nearby landfill/dumpsite. Additionally, the practice of open dumpsites in most African countries has direct link with air pollution. This is because burning of waste heap leads to the release of green house gases into the atmosphere. This act has contributed significantly to global warming as well as precursor to varied health challenges [16]. This paper is aimed at assessing the physico-chemical properties and deleterious heavy metal (Pb, Cr, Cu, Zn, Ni and Fe) present in leachate obtained from Ikhueniro dumpsite and evaluates its impact on groundwater resources in relation to human health. The outcome will suggest a possible and effective solid waste management scheme that will promote green environment for sustainable development. The overall outcome will contribute significantly to knowledge by providing a robust scientific data with evidence based as well as create public awareness of the dangers associated with the practice of open dumpsite. This will assist in policy formulation that will enhance effective waste management. It will also lead to the enforcement of existing environmental laws geared towards sustainable development goals.

1.1 Ground Water Quality Situation in Benin City

Groundwater under study is within the Benin Formation which is currently under serious threat as a result of environmental mismanagement of solid waste dump, the use of injection wells as flood control and direct introduction of effluents from several fish ponds into the aquifer that

supports over 30,000 boreholes [17]. This was confirmed by recent report of Erah et al. [18], Akujieze and Irabor [4], Imasuen and Omorogieva, [19] that groundwater in some areas of high anthropogenic activities has been seriously impacted with deleterious metals. The current study is to expand the research to open dumpsite environment were human beings live close to and adequately provide measures and suggest management scheme to ameliorate the situation. This will fast tract the attainment of United Nations' agenda six of availability and access to clean water for all by the year 2030.

2. MATERIALS AND METHODS

2.1 Study Site and Geology

The study area is within latitude $06^0$19'38.1''and longitude 05°44'.5.2''on the south-eastern portion of Benin metropolitan City, Edo, Nigeria. The area is classified under Benin Formation; the youngest sequence in Tertiary Niger Delta Sedimentary Basin [20]. The Formation is one of the most prolific sources of groundwater and it is made up of massive, highly porous, fresh water bearing sandstone with thin shale inter-beds which is thought to have originated from braided stream. It is thicker in the central onshore portion where it is about 1970 m (1.97 km) and thin towards the delta margins. It is an important section of Benin metropolitan City being a nodal town with high influx of immigrants engaged in farming and commercial activities. It is also an exit rout to neighbouring state and a host to several factories as well as one of main dumpsite servicing Benin City [11]. The study covers an area of 2,033 km² with a population of 121,749 and a population density of 59.89 km^2 according to Edo State Bureau of Statistics [21] and the National Population Commission (2006). The relief is low-lying except in the north western part where it is marked by undulating hills rising to a peak of about 672 meters above sea level [22]. The climatic condition of the area is classified under tropical climatic belt characterized by two distinct seasons namely the wet and the dry season (Fig. 1). The dry season usually commences from early November to late March whereas the wet season begins from late March to early November. The dry season is usually longer in the northern part of the country than in the southern part where rainfall is experienced throughout the year. The vegetative cover is light and scattered due to urban development. Generally, tropical climate is characterized with huge and tall trees which serve as canopy that prevent the sunlight from reaching the ground [23]. The annual mean temperature is 27°C with an annual range of 1°C–2°C. This implies that temperature is high throughout the year. The annual rainfall is usually more than 1500 mm (60 inches) with an average relative humidity of over 60%.

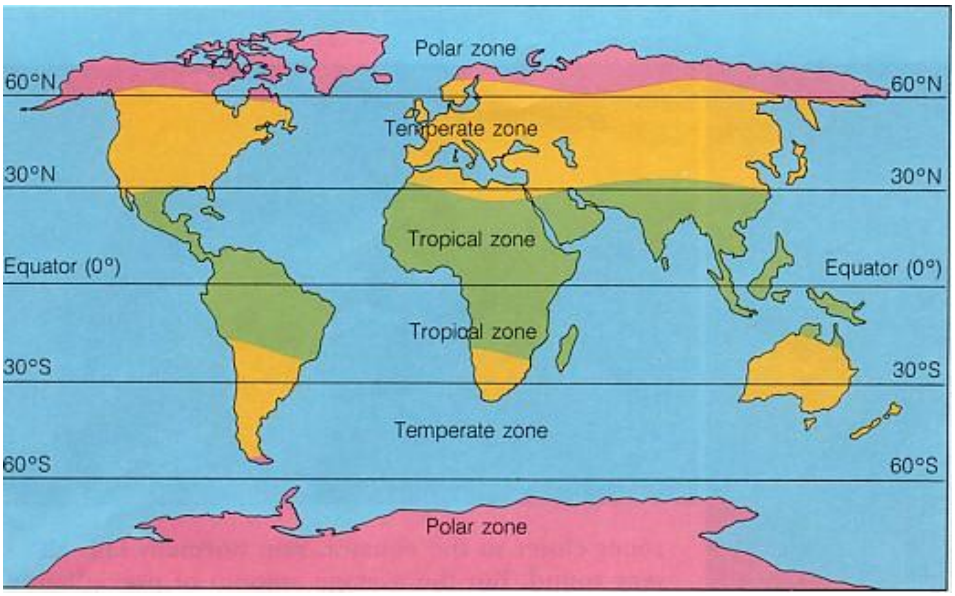

Fig. 1. World climatic belt [24]

2.2 Methodology

Extensive field work which includes field observation and data acquisition was carried out followed by ground reconnaissance survey. The first step was to review past and present literature on groundwater pollution and environmental mismanagement. The second step was the collection of raw leachate by grab sampling from a retention pond at the dumpsite in a two (2) litre plastic container for physicochemical analysis using standard methods prescribed in American Public Health Association [25,26] for analyzing water and waste water. Parameters like electrical conductivity (EC), pH, total dissolved solid (TDS) were measured in situ with conductivity meter and pH meter respectively. Trace metals were analyzed with Atomic Absorption Spectrophotometer (AAS) model 969 Unicam series with air acetylene at Central Labouratory of Faculty of Agriculture, University of Benin, Nigeria.

2.3 Secondary Data Collection/Acquisition

Secondary data of previous research was obtained with the permission from the authors [11], Omorogieva and Imasuen, 2018). The secondary data set include six boreholes logs obtained from existing boreholes in the vicinity of study.

3. RESULTS AND DISCUSSION

3.1 Impacts of Leachate from Solid Waste Dumpsites on Groundwater and Surface Water Resources

Data set consisting of previously published six (6) correlated borehole logs and results of specific heavy metal of known environmental and public health concern were obtained from Omorogieva and Imasuen [6] to assess the impact of the leachate on the surrounding surface and groundwater (Fig. 2). Fig. 3 shows the position of the borehole and their corresponding lithology as well as depth to water table. On the other hand, Table 1 summarizes the physicochemical results obtained in this study.

It was observed that quality of groundwater within the areas was significantly impacted by some of the heavy metal (Pb, Ni and Fe in GW1, GW2, GW5 and RW) assessed. The value of Pb obtained ranged from 0.03 – 0.05 mg/L compare to World Health Organisation recommended value of 0.01 mgL. On the other hand, Ni and Fe concentration were higher than the recommended value of 0.02 mg/L and 0.03 mg/L by WHO [27,28] and SON (2006) respectively. Excess of Pb in drinking water and soil have been reported to cause chronic and acute ailment like low intelligent quotient (IQ) especially in children under the age of five. It can also damage vital organs in the human system and more worrisome, Pb can be inherited from one generation to another [29,30,31]. On the other hand, excess concentration of iron (Fe) in human liver and other vital organs in the body can cause gene mutation a situation known as hemochromatosis and harbinger for cardio-vascular diseases as pointed out by Elis et al. [32], ATSDR [33] and Omorogieva (2018). It is important to mention that continuous dumping of waste influenced by climatic condition and geology of the terrain would eventually impact nearby boreholes in the direction of groundwater movement as observed in the current study. The elevated concentration of heavy Pb, Ni and Fe could be attributed to the activities of the dumpsite environment which include dumping of solid waste of various kinds [Nagarajah et al., 2012, [34,35]. Conversely, groundwater obtained from borehole tagged GW2, GW5 and river water (RW) in (Fig. 2) revealed a low concentration Pb, Cr, Cu, Zn, Cd, Ni and Fe and do not pose significant threat to the groundwater resources compared to borehole samples tagged GW1, GW3, GW4 and RW.

3.2 Suggested Leachate Management Techniques

The most important start off point in leachate management is the understanding of its source, composition, flow rate and the volume generated. This basic knowledge is the key to the designing of waste management reservoir and adoption of best techniques [36]. This is the reason why technology cannot be overemphasized in environmental and waste management practice. For example, in a well structured landfill, there would be a protective material (linage) that is expected collect or restrict percolating leachate. The leachate trapped would be collected and treated appropriately before discharging into water bodies vis a vis the environment. In addition, application of strategic sustainable waste and materials management as well as adherence to Environmental Impact Assessment

(EIA) when siting a waste dumpsite would be an solid wastes management [37] Where these key principles are applied, the risk of groundwater contamination, environmental degradation as well as atmospheric pollution will be minimized [38]. In this study, it was observed that countries with advanced technology like United Kingdom and German, and some states/province that employ landfill technique like Lagos Nigeria and Malaysia as well as the application of the 4Rs (recycling, reduce, reuse and recovery) in wastes management had relatively low concentration of environmental pollution indices measured in this study even though some of the study locations effective tool in environmental and are situated in areas of high rainfall zone that may facilitate leachate generation. The waste management hierarchy is an inverted triangle (Fig. 4) that demonstrates effective waste management strategies.

Details can be found at: https://www.google.com/search?q=inverted+triangle+of+waste+management&ie=utf-8&oe=utf-8. According to the United Nations Environmental Program [39], enforcement of environmental policy to comply with the 4Rs of waste management technique, the challenges

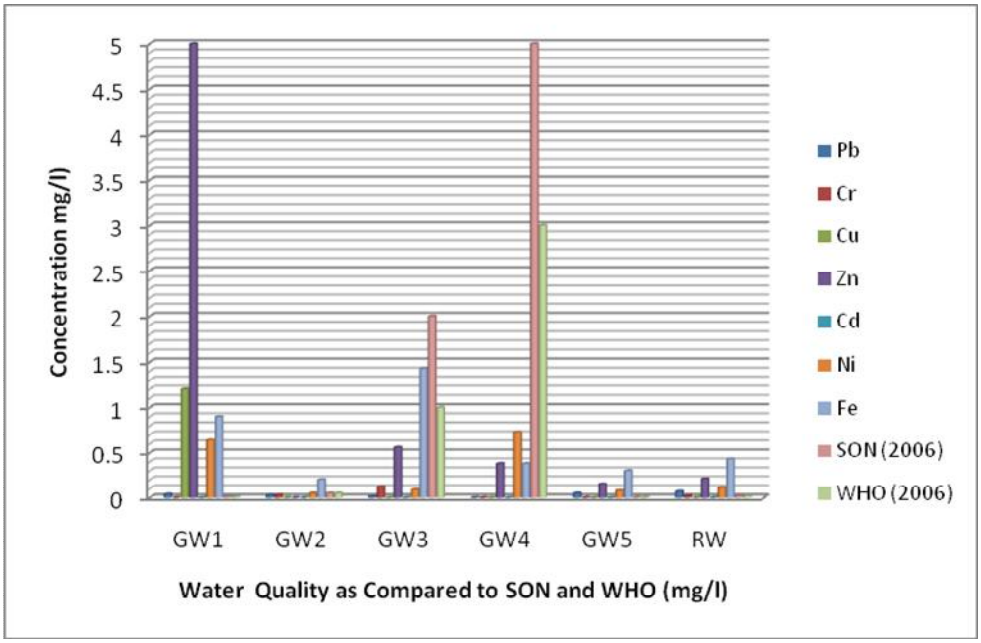

Fig. 2. Comparison of heavy metals with [41] and WHO [27]

Table 1. Physicochemical characteristics of groundwater from surrounding aquifer in the study area mg/L in Omorogieva

Parameters	Leachate	GW1	GW2	GW3	GW4	GW5	RW	WHO [27]	SON [41]
pH	7.70	6.8	6.33	5.71	5.78	6.2	6.11	6.5-8.5	6.5-8.5
EC	1557	400	70	84	95	58	83	1000	1000
TDS	550	200	35	42	47	29	41	250	250
Pb	6.46	0.04	0.03	0.01	0.001	0.05	0.07	0.01	0.01
Cr	4.11	ND	0.03	0.12	ND	ND	0.02	0.05	0.05
Cu	22.56	1.2	ND	ND	0.001	ND	0.001	2.00	1.00
Zn	I8.70	5.00	ND	0.56	0.38	0.15	0.21	3.00	5.00
Cd	5.02	ND	ND	ND	ND	ND	0.001	0.003	0.003
Ni	4.15	0.64	0.05	0.09	0.73	0.08	0.11	NA	0.02
Fe	500	0.9	0.2	1.43	0.38	0.3	0.43	0.3	0.30

NA = Not Available, ND = Not Detected, SON = Standard Organization of Nigeria, WHO = World Health Organization, EC = Eclectrical Conductivity (uS/cm) and TDS= Total Dissolved Solid

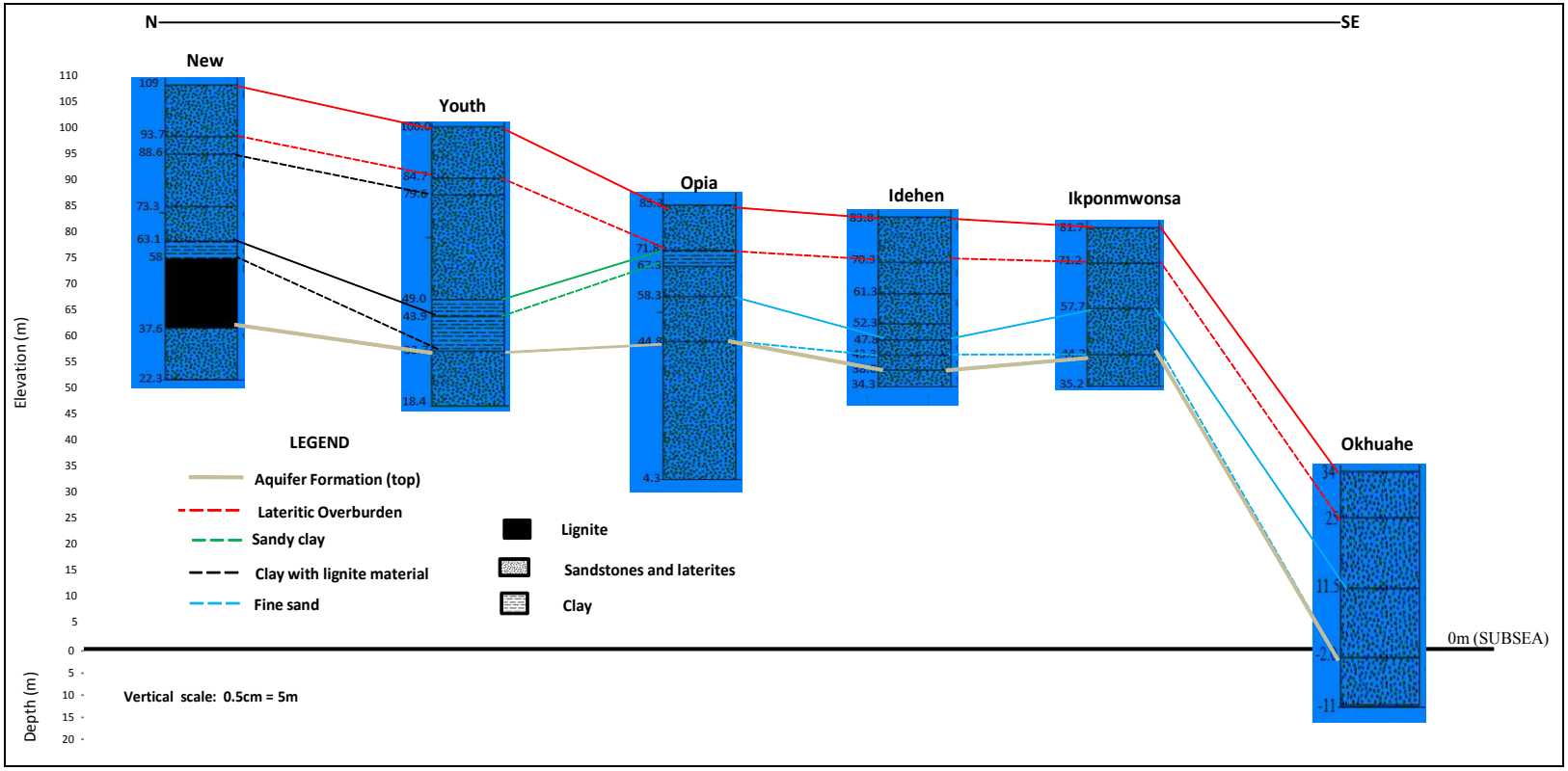

Fig. 3. Correlation of borehole logs in the study areas after Omorogieva and Imasuen [6]

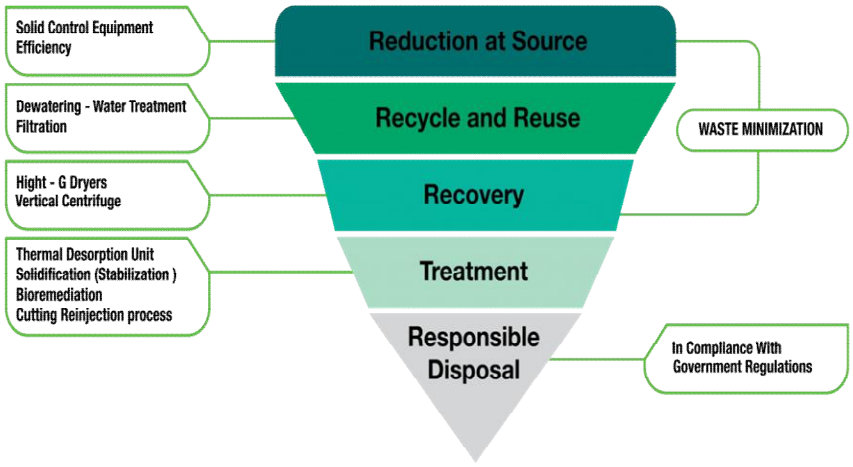

Fig. 4. Inverted triangle for wastes management [24]

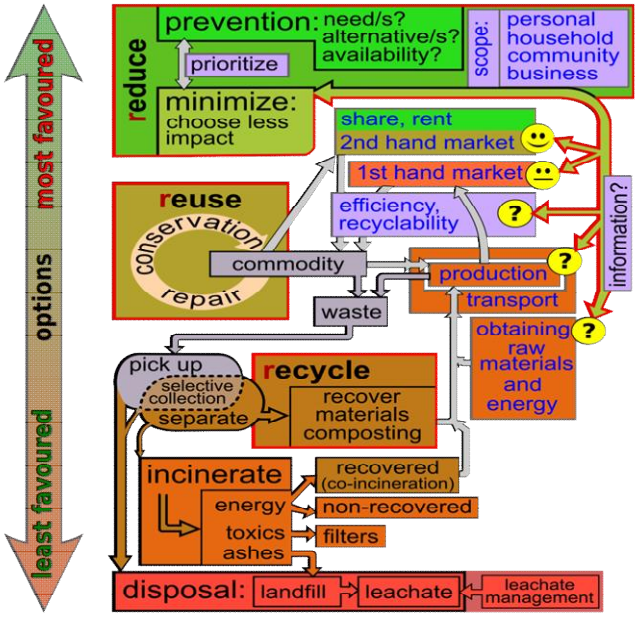

Fig. 5. Enhanced version of waste hierarchy [39,40]

associated with wastes generation and poor management control will pave way for wealth creation and opportunities as experienced in Europe and other parts of the globe. The step by step approach and detailed procedure is outlined in Fig. 5 [24]. Additionally, proper focus on waste education and promotion of wastes management practices particularly to community groups, primary and post primary schools, business owners, institutions and organisations as well as early learning centres would alleviate the challenges posed by leachate and poor wastes management on the geoenvironment [40]. Although it is cost effective, long term planning coupled with concerted effort of all stakeholders (government, opinion leaders and individuals) would certainly yield the desire result that will promote sustainable environment for sustainable development.

4. CONCLUSION

Leachate being hazardous and deleterious environmental contaminants source, is influenced by age, content and climate. Lack of managerial techniques and supporting

government policy as well as inadequate enforcement of existing environmental laws enhances its occurrence. Consequently, there would be negative impacts on groundwater resources, unfriendly environment leading to environmental degradation and disease outbreak. It was observed that groundwater samples tested for heavy metal Pb, Cr, Cu, Zn, Cd, Ni and Fe in borehole tagged GW1, GW2, GW5 and RW within and around the study site were significantly impacted with Pb, Ni and Fe while GW2, GW5 and RW were lower in concentration of Pb, Cr, Cu, Zn, Cd, Ni and Fe. Although, the concentrations of few contaminants do exceed the recommended value by national and international regulatory agencies for drinking water, the quality of groundwater in the study area represent a major risk to public health and therefore call for concern.

5. RECOMMENDATIONS

Waste management education should be introduced into the Nigeria curriculum from the grass root.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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