ABSU Journal of Environment, Science and Technology
Available online at: https://www.abiastateuniversityjournals.com/
https://doi.org/10.83316/0zq8-xe55
Original Research Article

Type of the Paper (Research Article)

Assessment of the Concentration of Heavy Metals in a Municipal Solid Waste Dumpsite Leachate

Ibeh, O.O[1*], S. S. Udochi[2] and I O. Okafor[3]

[1]Genetics and Molecular Biology Unit, Department of Animal and Environmental Biology, Abia State University, Uturu, Nigeria
[2]Toxicology Unit, Department of Animal and Environmental Biology, Abia State University,Uturu, Nigeria
[3]Physiology Unit, Department of Animal and Environmental Biology, Abia State University,Uturu, Nigeria

***Corresponding author. E-mail:** solaibeh@yahoo.co.uk, leosola@yahoo.com

ARTICLE INFO

Article history:
Received 15 May 2020
Revised 20 June 2020
Accepted 4 July 2020
Published date

Abstract

Although municipal solid waste landfills are an indispensable part of modern-day society, the presence of heavy metals in leachates from such pose a contamination threat to ground water and surface water, especially if the landfill is unlined. The assessment of physicochemical characteristic and heavy metals in an unlined landfill at Nekede, Nigeria were carried out. Leachate samples were collected from actual streams from different locations in the landfill and analyzed using standard analytical procedures. The results show that certain heavy metals contained in the leachate were above permissible limits of drinking water and waste water discharge standards set by international regulatory bodies. Mn, Zn, Cd, Cu, Hg, As, Ni and Pb were in concentration ranges of 0.16-0.93,1.12-7.34,0.02-0.05,0.15-1.62,0.16- 0.27, 0.15-0.20, 0.28-0.62 and 0.12-0.36mg/100g respectively, which are several multiples of the acceptable standards. In the light of the potential of this leachate to contaminate the surrounding surface and groundwater sources in the vicinity of the landfill, appropriate control measures should be taken by the concerned authorities to rehabilitate the landfill and also to continuously monitor the groundwater sources around the area in order to contain any contamination that might occur.

Keywords: Heavy metals, groundwater, drinking water, landfill

1. Introduction

The global accelerated process of industrialization, urbanization, and population growth, coupled with the ever-increasing effort at increasing the standard of living by most countries, has resulted in increase in solid waste generation. On the basis of source, solid wastes can bebroadly classified into household/municipal; industrial (hazardous) and biomedical/hospital (infectious) waste. However, as a result of the growth of metropolitan cities all over the world, municipal solid wastes (MSW) constitute the greater percentage of pollution from solid wastes. One of the major reasons is that the consequent change in lifestyle and food habits in urban cities has had a profound effect not only on the volume but also on the composition of municipal solid waste. Municipal solid waste is a type of solid waste, commonly referred to as trash or garbage, consisting of household waste, construction and demolition debris, sanitation residue and waste from streets. This could range from common wastes such as food wastes, paper, plastic, wood, leather, glass, metals, ashes etc. to special wastes such as bulky items, consumer electronics, batteries, oils, tyres, etc. It could also include wastes from light and heavy manufacturing, construction sites, power and chemical plants etc. It often contains all sorts of hazardous and toxic wastes such as pathogens from hospitals or homes; pesticides and herbicides from public parks and private gardens; combustibles such as carbide, gasoline, oil, grease, and ash residues from industrial, commercial, or residential sources; waste explosive materials such as small arms; spray or paint containers; industrial chemicals, both organic and inorganic; wastewater treatment residues such as septic tank, and sewage treatment plant sludges; feaces from children's disposable diapers; dead animals etc.

Over the last few years, the consumer market has grown rapidly, leading to products being packed in cans, aluminum foils, plastics, and other non-biodegradable items and the outcome is incalculable harm to the environment. The wastes from pharmaceutical and personal care products, spent oil from machines, tyres, electrical and electronic wastes etc. on the other hand may contain flammable, toxic, carcinogenic and or corrosive elements and this may pose serious threats to life forms (Bakare *et. al*.,2013). Municipal solid wastes may thus constitute potential hazards to the environment and may be very detrimental to life if not properly managed. There are thus serious international concerns about the potential environmental hazards posed to biolife and the attendant health implications to humans and other living organisms. Different methods employed in the disposal of municipal solid wastes include open dumping, incineration and landfilling. Land filling is the most common method for the disposal of solid wastes, accounting for the disposal of about 95% of total solid wastes collected all over the world (Kurniawan *et. al.,* 2006) and it also remains the predominant management method for the disposal of municipal solid wastes. In the developed nations of the world, sanitary landfills are utilized, while most developing countries including Nigeria, utilize open dumping in low value sites without facilities for gas collection and leachate treatment.

A major problem associated with MSW landfill is that of leachate generation and the associated potential harmful effects on the environment. Leachate is formed by the precipitation that falls into the landfill coupled with any disposed liquid waste, resulting in the extraction of the water-soluble compounds and particulate matter of the waste (Samuding, 2009). The chemical composition of MSW leachate depends on the type and amount of waste, landfill age and the environmental conditions (Fan *et. al.,* 2006). Leachate from municipal landfills typically has high values of dissolved solids, COD, slightly to moderately low pH, hazardous constituents such as volatile organic compounds and heavy metals (Hong *et. al*., 2002). Heavy metals are metallic elements that have relatively high density (>5.6g/cm3) and are toxic even at low concentrations; they are non-biodegradable and undergo ecological cycle (Christensen *et. al*., 2001). Concentrations of heavy metals in landfill leachates are sometimes low and may not pose a great deal of threat to groundwater pollution (Bjerg *et. al.,* 2003) but when present in high concentrations, they can cause even a little volume of leachate to be highly toxic (Sawaittayothin & Polprasert, 2007). Heavy metals are thus the most toxic and environmentally dangerous pollutants in leachates and they can contaminate soil and water due to their leach ability and mobility (Samuding, 2009). There lease of leachate to the ground water may present a danger to the environment and to aquatic species if the leachate-contaminated ground water plume discharges to wetlands or streams and this can render an aquifer unusable fordrinking (Christensen *et. al*., 2001). Heavy metals in leachates may lead to phytotoxicity (reduced plant growth) due to phytoaccummulation in plant tissues above tolerable threshold values. They could also induce clastogenic and aneugenic effectsin living organisms including mitosis and cytokinesis disturbances (Fenech *et. al.,* 1999). The heavy metals commonly found in leachate include chromium, cadmium, lead, mercury, copper, nickel, arsenic, manganese, and zinc (main elements generally of concern) etc. but the actual concentration of the individual component varies from one land fill to another (AlRaisi *et. al*., 2014). They can also form metal colloids or complexes, particularly with organic matter (Jensen & Christensen, 1999).

This study was undertaken with the objective of assessing the heavy metals' concentration of the leachate of the unlined MSW landfill at Nekede in Owerri metropolis of the southeast of Nigeria. The population in Owerri metropolis has increased significantly over time from an estimated value of 109,500 in 2006 to a value of 1,001,873 in 2016. This has been accompanied by increased waste generation and disposal. The waste generation per capita per day has been estimated at 1474.33 m3 (Nwoke, 2013). Improper solid waste management (SWM) is a major environmental problem in the Owerri metropolis due to non-availability of modern engineered landfills, thereby posing serious pollution risk to the environment. There are several dumpsites within the Owerri metropolis but the Nekede landfill is one of the main waste disposal sites near the city. The potential hazardous effects of the metals are also discussed.

2. MATERIALS AND METHODS

Description of study area

The landfill is located in Nekede (50 26' 0" North, 70 2' 0" East) at a low value area where deep gullies have been artificially created by sand evacuation from a major river in the city, the Otamiri River, and the consequent erosion (Figure 1 a and b). The landfill receives wastes from domestic and commercial sources. It is an unlined open pit bordered by farm lands and residential houses. Wastes transported to the site by private sector partnership (PSP) trucks are dumped indiscriminately without any form of sorting whatsoever. The sampling was carried out in the month of July.

Leachate collection/sampling

Since the landfill was not equipped with a leachate collector, leachate samples were collected from actual leachate streams at the base of the landfill in the solid waste dumping site using 5L plastic containers previously rinsed with distilled water. The samples were transported to the laboratory, stored at 4ºC and analyzed within 2 days. A total of 4 leachate samples (L1-L4) were randomly collected from different locations in the landfill for monitoring purpose. The physicochemical parameters (pH, biochemical oxygen demand -BOD, chemical oxygen demand -COD, total hardness, total dissolved solids, major cat- ions such as Ca2+, Mg2+, and iron, major anion such as Cl- were determined. All analyses were repeated thrice until concomitant values were obtained, and all tests were carried out according tostandard methods (APHA, 1998).

Heavy metals analyses

The elements in the digested leachate were determined using atomic absorption spectrophotometer (AAS). 50 ml of the leachate in each case was measured and weighed in a 100 ml crucible and evaporated to dryness on a hot plate. The crucible containing the residue was transferred to a muffle furnace and incinerated at 550 ºC for about 4 h. it was cooled in a dessicato and the ashed residue wasdissolvedwithabout5mlconcentrated HCL, diluted with deionized water, filtered and made up to the mark in a 100 ml volumetric flask with deionized water. Heavy metal concentration was analyzed with BUCK 205 atomic absorption spectrophotometer (AAS) using flame atomization. Results are expressed on dry weight basis of each component.

Table 1: Results of Physicochemical characteristics of Nekede landfill leachate samples from different locations in the study area

Parameter	LI	L2	L3	L4	aNEMA	bUSEPA	cWHO
Colour	Light brown	Light brown	Dark brown	Dark brown	NGV	NGV	
pH	8.96	8.77	9.33	9.70	6-9	6.5-8.5	
Electrical conductivity EC)	1.92	1.58	0.80	4.57			400
% Organic carbon	0.32	0.16	0.14	0.24			
% Organic matter	0.55	0.28	0.24	0.41			
Ca	19.04	15.34	32.27	12.76	100		100-300
Mg	4.20	10.60	6.24	8.36	100		100-300
P	18.13	14.47	31.03	12.02	2.0	NGV	NGV
SO4	15.04	10.33	17.71	19.43	100	NGV	NGV

P and SO_4 are in ppm; EC is in mS/cm while all other values are in mg/100g; NGV –No guideline value. aNational Environmental Management Authority (1999) (nema.go.ug/effluent discharge regulations) bUnited States Environmental Protection Agency(2006)(www.epa.gov/safewater/mcl.html)

cWorld Health Organisation (2008) (www. who.int/whr/2011/en/)

Table 2: Results of heavy metals concentration in Nekede landfill leachates

Heavy metal	LI	L2	L3	L4	NEMA	USEPA	WHO
Hg	0.27	0.20	0.24	0.16	0.01	0.001	0.006
Li	0.51	0.72	0.65	0.66	NGV	NGV	NGV
B	0.36	0.19	0.21	0.27	5	5.0	0.5
Se	0.08	0.06	0.10	0.06	NGV	NGV	0.04
As	0.20	0.19	0.17	0.15	0.2	0.01	0.01
Ni	0.28	0.29	0.62	0.29	1.0	NGV	0.07
Cr	0.07	0.07	0.06	0.08	0.01	0.05	0.05
Co	0.02	0.06	0.04	0.04	NGV	NGV	NGV
K	84.36	57.77	31.56	174.43	NGV	NGV	NGV
Na	40.95	43.57	37.35	50.61	NGV	NGV	NGV
Mn	0.78	0.93	0.59	0.16	1.0	0.05	0.1-0.4
Fe	10.89	2.24	9.85	6.82	10	0.3	0.3
Cu	0.62	0.28	0.37	0.15	1.0	1.0	2.0
Zn	6.56	7.34	4.10	1.12	5.0	5.0	0.01-0.05
Cd	0.05	0.03	0.02	0.03	0.1	0.005	0.003
Pb	0.36	0.17	0.15	0.12	0.1	0.01	0.01

P and SO_4 are in ppm; EC is in mS/cm while all other values are in mg/100g; NGV - No guideline value aNational Environmental Management Authority (1999) (nema.go.ug/effluent discharge regulations) bUnited States Environmental Protection Agency (2006) (www.epa.gov/safewater/mcl.html)

cWorld Health Organisation (2008) (www. who.int/whr/2011/en/)

4. DISCUSSION

The results of the physicochemical characteristics and heavy metals concentrations are presented in Table 1and Table 2. The leachates from the newer waste deposits were light brown in colour while those from the older ones were dark brown in colour. The dark brown colour observed in the older leachate is mainly due to the oxidation of ferrous to ferric form and the formation of ferric hydroxide colloids and complexes with fulvic/humid substance**.** The significant variation of leachate quality from different collection locations shows a wide variation in the concentrations of leachate parameters within the dumping site. The decomposition, stabilization, and removal of contaminants from a landfill depend on numerous factors such as composition of the wastes, degree of compaction, temperature, various inhibiting materials present, presence of moisture, input and output of water, rate of water movement and hydrological characters. Thus, the qualiy of leachate is mainly the result of physical, chemical, biological processes and the presence of inhibitory and toxic materials (Yoshida *et. al.,* 2002)

The results show high pH values of the leachate samples ranging from 8.77-9.70 Alkaline pH is normally encountered at landfills 10 years after disposal (El-Fadel *et. al*., 2002) alkalinity might be due to bicarbonate, a large amount of mineral species are expected to exist in leachate in bicarbonate form (Seo *et. al*, 2007). High pH indicates low metal solubility since metal mobility is controlled by physical sorptive mechanisms and landfills have an inherent *in situ* capacity for minimizingthe mobility of toxic metals (Pohland *et. al*., 1993. This fixing of heavy metals reduces the risk of direct toxic effects due to ingestion of leachate contaminated ground water. The low EC values observed in all theleachatesamplesindicatetheabsenceof dissolved inorganicmaterials.

On the basis of the average concentrations, the heavy metals in the leachate samples were in the following order: Fe>Zn>Hg>Li>Mn>As>Ni>Cu>Bo>Pb> Se>Cr>Co>Cd. Considerable variations of heavy metals in leachates have also been reported by many workers (Adeolu *et. al*., 2011; Al Raisi *et. al*., 2014). The wide variety of heavy metals detected in the different leachate samples clearly indicate that diverse wastes are beign disposed in the landfill. The high concentration of Fe shows that a lot of of iron and steel scraps are being disposed in the landfill while the high values of Zn indicates the disposal of batteries, fluorescent lamps, a variety of food wastes as well as tyre burning at the landfill site. The significant concentrations of Hg, Mn, As show that electrical appliances, bleach and disinfectants are part of the waste stream I the landfill while Ni, Cu, Bo and Pb indicate the disposal of paints, bottle caps, pharmaceuticals, cosmetics and storage batteries (Kaani and Gadhimathi, 2013). Heavy metals are of great concern as contaminants because they bind to organic matter but as the organic matter decomposes, heavy metals may become less trapped (Adeolu *et. al*.,2011).

Retention reactions are important processes that govern the fate of chemicals such as heavy metals in groundwater (Kulikowska & Klimiuk, 2008). Substantial metal particles may have lethal impacts on plants andother life forms and even humans, and their poisonous quality is connected to their mobility in soil. They can also have antagonistic and synergistic behaviours among themselves. Moreover, heavy metals in the soil from antropogenic sources tend to be more mobile, hence bioavailable than pedogenic and lithogenic ones (Kaasalainen & Yli-Halla, 2003).

Although landfills are an indispensable part of everyday living, they may present long- term threats to ground water and surface waters that are hydrologically connected. Today's society may thus be placing a burden on upcoming generations to address future landfill impacts. There is therefore a dire need for a shift from waste disposal to sustainable waste management including reduction, minimization, recovery, recycling, and reuse.

5. Conclusions

A conclusion section is necessary. The conclusion should summarize the key points of the paper without simply repeating the abstract. It should also discuss the significance

Acknowledgement

We hereby acknowledge that this research work was funded by the Tertiary Education Trust Fund (TETFUND) intervention funds.

REFERENCES

Adeolu, O., Ada, O.V., Gbenga, A.A. & Adebayo, O. A. (2011). Assessment of groundwater contamination by leachate near a municipal solid waste landfill. *African Journal of Environmental Science and Technology. 5(11),* 933-940

Al Raisi SAH, Sulaiman H Suliman FE & Abdallah O (2014) Assessment of heavy metals in leachate of an unlined landfill in the Sultanate of Oman. *International Journal of Environmental Science and Development 5(1),* 60-63

American Public Health Association - APHA (1998). Standard methods for the examination of water and waste water. 220th Edition, Washinton DC.

Bakare A.A., Alimba C.G. & Alabi A.O.,(2013) Genotoxicity and Mutagenicity of Solid Waste Leachates: A Review. *African Journal of Biotechnology. 12(I27), 4206- 4220*

Bjerg, P.L., Albrechtsen, H.J., Kjeldsen, P., Christenssen, T.H., Cozzareli, I.M. & Heinrich, D.H. (2003). The groundwater geochemistry of waste disposal facilities in (ed) Treatise on Geochemistry, Pergamon, Oxford,. 579-612.

Christensen T.H., Kjeldsen P., Bjerg P.L.&, Jensen D.L., (2001) Biogeochemistry of Landfill Leachate Plumes. *Applied Geochemistry. 16, (7-8), 659-718*

El-Fadel, M., Bou-Zeid, E. Chachine, W. & Alayli, B. (2002). Temporal variation of leachate quality from pre-sorted and baled municipal solid waste with high organic and moist content. *Journal of the Environment,* 22(3):269- 282

Fan H.J., Shu H.Y., Yang H.S., & Chen W.C., (2006) Characteristics of Landfill Leachates in Central Taiwan. *Sci. Total Environ. 361, (1-3,: 25-37*

Fenech M Crott JW Turner J & Brown S (1999) Necrosis, apoptosis, cytostasis and DNA damage in human lymphocytes measured simultaneously within the cytokinesis- block micronucleus assay: description of the method and results for hydrogen peroxide. *Mutagen.* 14 (6), 605-612.

Hong K.J., Tokunaga S & Kajiuchi T. (2002). Evaluation of remediation process with plant-derived biosurfactant for recovery of heavy metals from contaminated soils. *Chemosphere*. 49,379-387.

Jensen D.L., & Christensen T.H., (1999) Speciation of Heavy Metals in Landfill- Leachate Polluted Groundwater. *Water Research. 33 (11), 2642-2650*

Kanmani, S. & Gandhimathi, R. (2013) Assessment of Heavy Metal Contamination in Soil Due to Leachate Migration from an Open Dumping Site. *Applied Water Science, 3, 193-205*

Kaasalainen M., & Yli-Halla M. (2003) Use of Sequential Extraction to Assess Metal Partitioning in Soils. *Journal of Environmental Pollution.* 126(2), 225-233.

Kulikowska D. & Klimiuk E. (2008). The effect of landfill age on municipal leachate composition. *Bioresource Technology,* 99 (13), 5981-85

Kurniawan T.A., Chan G.Y.S., Lo W.H.&, Babel S., (2011) Physico-Chemical Treatment Techniques for Wastewater

Laden with Heavy Metals. *Chemical Engineering Journal. 118, (1-2),83-98*

National Environmental Management Authority - NEMA (1999) (nema.go.ug/effluent discharge regulations)

Nwoke, H.U. (2003). Generation rate of solid waste in Owerri metropolis, Imo State, Nigeria. *Continental Journal of Environmental Science*. 7(1), 8-10

Pohland, F.G., Cross, W.H., Gould, J.P. & Reinhart, D.R. (2002). Behaviour and assimilation of organic and inorganic priority pollutants codisposed with municipal refuse. National Technical Information Service, Springfield, pp. 197.

Samuding K., Abustan I., Rahman M.T.A. & Isa M.H. (2009). Distribution of Heavy Metals Profile in Groundwater Systemat Solid Waste Disposal Site. *European Journal of Scientific Research 37(1), 58- 66*

Sawaittayothin V., & Polprasert C., (2007) Nitrogen Mass Balance and Microbial Analysis of Constructed Wetlands Treating Municipal Landfill Leachate. *Bioresource Technology. 98, (3),565-570*

Seo, D.J., Kimb, Y.J., Hama, S.Y. & Lee, D.H. (2007). Characterization of organic matter in leachate discharged from final disposal sites which containedmunicipal solid waste incineration residues. *J Hazard Mater* 148,679-692.