Characterization of leachates from a municipal solid waste landfill site in Ibadan, Nigeria

OO Aluko[1], MKC Sridhar[1], PA Oluwande[1]

[1] Division of Environmental Health, Department of Epidemiology, Medical Statistics and Environmental Health, Faculty of Public Health, College of Medicine, University of Ibadan, Nigeria.

Correspondence: OO Aluko, Telephone: 234-08034014364 Email: olufeming@yahoo.com

Abstract

Leachates have been implicated in environmental pollution, developmental anomalies, birth defects, surface and groundwater pollution worldwide. The knowledge of the quantity and composition of leachates usually gives an insight into appropriate, effective and sustainable treatment approach. Hence, the study documented the physical, chemical and trace metals characteristics of leachates from the major repository of municipal solid wastes in Ibadan.

The study was descriptive and analytical in design aimed at documenting the quality of leachates with the intention of designing a cost effective treatment method. Integrated samples of leachates were collected during wet and dry periods and analysed for pH, Suspended Solids (SS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammonia, Nitrate Phosphate, Sulphate and trace metals among others. Leachates were alkaline and amber in appearance.

Analyses of samples revealed variation during wet and dry periods, respectively in turbidity (83.4 and 139 Formazin Turbidity Units (FTU)), SS (213.6 and 148 mg/l), BOD (990.6 and 675.0 mg/l). Mean concentrations of SS (176.9 mg/l), BOD (795.8 mg/l) and nitrogen (885.1 mg/l) mainly as ammonia were high and prevailed in leachate samples. Nitrate (0.58 mg/l), phosphate (2.2 mg/l) and sulphate (84.9 mg/l) values were within acceptable limits recommended by regulatory bodies in Nigeria. Iron predominates and total metals concentration (175.8 mg/l) exceeded the regulatory limit of 3 mg/l. The ratio of BOD/COD ranged from 0.11 – 0.40. Therefore, physicochemical and/or biological methods of treatment are required to treat leachates before they are discharged into the environment at the dumpsite to either eliminate, or drastically reduce, the short term and long term detrimental effects on ecology, public health and the environment.

Keywords: Environmental pollution, leachate characteristics, municipal solid wastes, landfill, Ibadan, Nigeria

Introduction

The post independence era in Nigeria has witnessed a series of political and socio-economic developments. Today, the nation comprises 36 States and a Federal Capital Territory in comparison with the initial four regions at independence in 1960. Over the years, there has been a considerable growth in the awareness of environmental pollution problems and it has become a major national and international political issue. Ibadan, the largest, and one of the most populous, cities in sub-Saharan tropical Africa is experiencing the problem of municipal waste management, principally as a result of unplanned development, rural-urban migration and natural increase within the city (Akinbiyi, 1992). Yet this remarkable growth rate has not been matched by improvement in the quality of the urban environment. Instead, the demographic expansion and increased industrial and commercial activities have caused an astronomical increase in the volume and diversity of solid wastes generated in Nigeria (Aluko, 2001).

Although solid waste is an asset when properly managed, its volume has continued to increase tremendously in recent times in Nigeria as a result of socio-economic development including wage increases. In Nigeria, much has been, and is being, invested on municipal solid waste management in cities. But, little progress has been made because of severe financial, technological and institutional constraints within the Public and the private sectors apart from erratic growth of housing units in the inner core of urban cities (Ojeshina, 1999; Omishakin and Sridhar; 1985).

Despite the best attempts at waste avoidance, reduction, reuse and recovery (recycling, composting and energy recovery), landfill and waste disposal sites are still the principal focus for ultimate disposal of residual wastes and incineration residues world-wide (Charlotte, 1998; Waite, 1995). The placement and compaction of municipal wastes in landfills facilitates the development of facultative and anaerobic conditions that promotes biological decomposition of landfilled wastes. Hence, leachates of diverse composition are produced, depending on site construction and operational practices, age of the landfill, landfill method, climatic and hydrogeological conditions and surface water ingress into the landfill (Campbell, 1993). Leachates therefore migrate vertically and laterally into the environment by direct discharge into the adjacent Omi stream serving about 16 communities around the landfill.

The realisation of the polluting effects of landfill leachates on the environment has prompted a number of studies. These include studies on domestic wastes (Sridhar et al, 1985), leachate quality (Aluko et al, 2000), as well as underground water quality (Loizidou and Kapetanios, 1993).

At the study site, leachates are discharged into the environmental media without treatment. This has resulted in low farm produce, release of obnoxious gases into the environment, contamination of the domestic water sources (Tairu, 1998). For treatment however, neutralisation, chemical treatment, gravel filtration, waste stabilisation pond and constructed wetlands, among other strategies can be investigated in order to develop a cost effective and sustainable method of treatment for leachates at the landfill site. This paper therefore aims to identify the composition of the landfill, with a view to estimating its polluting effects and to designing a sustainable, cost effective and environmentally friendly method of treatment.

Materials and methods

Study location

Ibadan, founded in 1829, has an estimated population of between 2-3 million. The city is situated at an average height of 200 m above sea level, drained by 4 river basins and surrounded by secondary rainforest as well as a savannah. Spatially, it sprawls over a radius of 12-15 km and experiences a mainly tropical climate with an estimated annual rainfall of about 1250 mm (UNCHS/UNEP, 1997). The landfill has been a dumpsite since 1994, incorporating drainage pipes and lined with clay and gravel, even though in reality, it is being used as an open dump. The site was predominantly a containment landfill that was upgraded and commissioned in 1998. The state-owned landfill sites are not properly managed since the operational practices at the site do not follow the standard, normal practices. The landfill covers about 6 hectares of land with solid wastes having being deposited to an estimated depth of about 1.5 meters. It has been used for municipal solid waste disposal for over 8 years. It receives domestic, industrial and institutional wastes by public and private waste management operators (Aluko, 2001). There are about 18 drains at the landfill downstream that collect leachate draining from the landfill into a central pond, from where leachates are discharged into Omi stream. This stream is the dominant source of water for about 16 villages in Ona Ara Local Government area, being used for domestic purposes and to process palm oil, which is their major local industry.

Leachate sampling and analyses

Leachate drains were strategically constructed to collect effluents from the waste mass into a pond by gravity. No precipitation had occurred in the week preceding sampling for dry period samples, while wet season leachates were collected during a rainy period. To determine the quality of leachates, integrated samples were collected from randomly selected leachate drains at the site (APHA, 1998, 1060A3). The samples were collected in well-labelled clean bottles that were rinsed out thrice prior to sample collection.

Analytical methods were according to “Standard methods for examination of water and wastewater” unless otherwise stated (APHA, 1998). Suspended solids and turbidity were determined using a portable data logging spectrophotometer, dialling (650 and 580) in the respective stored programmes, and results were expressed respectively in mg/l and FTU. Colour was determined by Lovibond colour comparator while pH was determined by glass electrode method with a standard calibrated pH. Dissolved solids, temperature and conductivity were metered in situ. An Atomic Absorption Spectrophotometer was used for metals analyses after samples were digested, using concentrated trioxo nitrate (V) and the volume made up to 50ml with de-ionized water. Dissolved oxygen (DO) was determined by Azide modification of Winkler's method. Open reflux method utilising potassium tetra-oxo chromate (VI) in boiling concentrated tetra-oxo sulphate (VI) solution in the presence of silver catalyst was used to determine COD while Nessler's method was used to determine ammonia. Nitrate was determined by phenoldisulphonic acid method (Taras, 1950) while phosphate was analysed by colorimetry using molybdovanadate method.

Results and discussion

The characteristics of leachates are shown in Tables 1.0, 2.0, 3.0 and 4.0. High concentrations of pollutants prevailed in leachates except for nitrate, sulphate and phosphate. This corroborated the findings of Tairu (1998), where a high incidence of mortality was reported among domestic animals, low farm produce and contaminated domestic water sources were reported and attributed to direct discharge of raw leachates into nearby environment at the landfill site. There is no threat of thermal pollution in Omi stream since leachates have an average temperature of 26°C. Leachates were amber coloured and alkaline with pH range of 8.03 to 8.28. This is typical of samples from aged wastes and such wastewater requires high coagulant dosage to ensure sweep coagulation of pollutants if chemical treatment is desired (Harrison, 1996).

Leachates produced during wet season were more alkaline as compared to those produced during dry period. Leachates collected during wet period showed higher concentrations of pollutants particularly for conductivity, SS, dissolved solids, BOD, COD, phosphate, lead, iron and zinc except in colour, turbidity, dissolved oxygen, ammonia, nickel, cadmium and manganese (Tables 1.0, 2.0 and 3.0). This could be attributed to surface water ingress into the landfill that promotes solubilisation of pollutants from actively decomposing waste mass into leachates emanating from the landfill site (Campbell, 1993).

The suspended solids (176.9 mg/l) and turbidity (114.3 FTU) values indicated the presence of organic and inorganic solids that can provide adsorptive sites for certain chemicals and biological agents.

The dissolved oxygen (1.94 mg/l) was quite low and cannot support desired aerobic organisms downstream. This may upset the ecosystem, encourage development of septic conditions and lead to proliferation of anaerobic biota that may produce anaerobic conditions in Omi stream. The ammonia value (855.1 mg/l) provides evidence of its release from decomposition of nitrogenous substances in refuse. There is no set standard for ammonia in wastewater aimed for discharged into surface waters in Nigeria even though it is highly toxic and lethal to most fish species even at low concentrations. Conversely, nitrate and phosphate values were within permissible limits (Ogban, 2000; Brock and Madigan, 1988). Iron (48.5 mg/l), manganese (22.6 mg/l) and zinc (12.0 mg/l) concentrations were high and may be responsible for unacceptable colour of leachates. The concentrations of lead (1.5 mg/l), cadmium (0.3 mg/l) and nickel (0.8 mg/l) were permissible for disposal at surface water or land according to the national regulatory standards (Table 3.0). Total metals concentration exceeded the national threshold value of 3 mg/l (Table 4.0). This may be hazardous to the ecosystem and public health since metals are cumulative toxicants that pose danger to organisms near the top of the food chain. It could also lead to bioaccumulation and bioconcentration of these metals in the food chain.

The characteristics of leachates made it mandatory for an appropriate and wise selection of a treatment method that can produce effluents that meet any given discharge standard. Experiments should be conducted at laboratory scale on possible treatment methods. It would have been easy if leachate treatment methods were transferable directly from one location to another. This is because leachates vary greatly in composition from site to site and, after a while, the treatment process initially selected may be inappropriate as the landfill ages (Horan, 1991). **Neutralisation** is a process for reducing the acidity or alkalinity of wastewaters by using either bases or acids to produce effluents with neutral pH. In the case of

Table 1.0: Physicochemical characteristics of wet, dry and combined leachate samples

Parameters	Wet season Mean ±SD n = 05	Dry season Mean ±SD n = 07	Combined samples Mean ±SD n = 12	FEPA's Standard
Temperature (°C)	25.66 ±0.75	25.76 ±0.98	25.66 ±0.84	< 40
pH	8.28±0.38	8.03 ±0.36	8.17 ±0.37	6-7
Colour (HU)	423.60±101.20	434.71±35.20	426.08±68.96	7
Turbidity (FTU)	83.40±37.35	139±33.03	114.25±42.46	---
Conductivity(μS/cm)	5662±2565.90	4807±1738.37	5155.75±2061.38	---
Total Solids (mg/l)	4819.6±1333.63	3883.43±1995.80	4270±1751.07	---
SS (mg/l)	213.60±99.54	148.71±51.48	176.92±77.91	30
TDS (mg/l)	4606±1367.05	3735±1981.42	4093.75±1743.28	2,000
Alkalinity (mg/l)	2208.40±1547.25	1421.43±838.54	1731.75±1206.84	---
Chloride (mg/l)	1606 ±765.44	1271.29±882.65	1450.08±802.49	600
Sulphate (mg/l)	111.18 ±44.66	65.33 ±32.53	84.86±42.79	500
DO (mg/l)	2.09 ±0.12	1.87±0.26	1.94±0.24	---
BOD (mg/l)	990.60±626.47	675.57±82.42	795.83±419.56	50
COD (mg/l)	3066.6±1538.46	2802.14±531.50	2914.50±1016.85	---

Table2.0: Nitrogen and phosphate changes of wet, dry and combined leachate samples

Parameters	Wet season Mean ±SD n = 05	Dry season Mean ±SD n = 07	Combined samples Mean ±SD n = 12	FEPA's Standard
Ammonia (mg/l)	622.26±178.65	1316.27±1299.95	855.13±775.34	---
Nitrate (mg/l)	0.47±0.18	0.58±0.37	0.58±0.29	20
Phosphate (mg/l)	2.31±1.28	2.07±1.87	2.2±1.56	05

Table 3.0: Trace metals composition of wet, dry and combined leachates

Parameters	Wet season Mean ±SD n = 05	Dry season Mean ±SD n = 07	Combined samples Mean ±SD n = 12	FEPA's Standard
Lead (mg/l)	1.693±0.64	1.34±0.89	1.490±0.783	< 1
Nickel (mg/l)	0.659±0.48	0.952±0.29	0.815±0.379	< 1
Cadmium (mg/l)	0.103±0.07	0.489±0.37	0.330±0.340	< 1
Iron (mg/l)	180.845±74.12	122.392±76.01	148.53±76.352	20.0
Manganese (mg/l)	22.623±12.87	24.854±9.90	22.634±10.645	05.0
Zinc (mg/l)	2.257±1.33	1.423±0.51	1.955±1.073	< 1

Table 4.0: Characteristics of leachates and national regulatory standards in Nigeria.

Parameters	Leachates	FEPA's Standard (recommended values)
Colour(HU)	426.1	7.0
Turbidity (FTU)	114.3	5.0
SS (mg/l)	176.9	30.0
BOD (mg/l)	795.8	50.0
Phosphate (mg/l)	2.2	5.0
Sulphate (mg/l)	84.9	500.0
Iron (mg/l)	148.5	20.0
Total metals (mg/l)	**175.8**	**3.0**

leachates from this dumpsite, Perchloric acid was used since leachates were alkaline. Neutralisation may be required prior to application of other treatment processes since it aids some dissolved particles to either flocculate or coagulate (Speight, 1996).

Gravel filtration (biofilter). This is a modified trickling filter, which entails construction of a circular or rectangular reactor that is filled with different sizes (25-100 mm) of permeable media, typically a bed of coarse gravel to a variable depth (1-3 m). Leachates will then be distributed evenly mechanically over the media and percolate through the media to be collected in an under drain system. Biofilm will develop on the filtration media after a period of acclimatisation and this microbial film is responsible for the purification of the effluents via degradation of the pollutants and incorporation of some nutrients into their cell mass. This method is comparatively simple to operate, having low running costs and being tolerant of short and toxic loading due to a short contact time between the wastewater and the microbial slime layer (Aluko, 2001). However, the loading rate would be determined after due experimentation for effective performance.

The waste stabilisation pond is a shallow excavation (1-3 m), which receives a continuous flow of wastewater. The degree of wastewater purification depends on either the length of the pond or the number of ponds in the series, and the retention time of the wastewater in the system (Horan, 1991). This system relies on sunlight for energy and incorporates diverse microbial flora, particularly algae and bacteria, to mineralise pollutants that are present in leachates. Purification is further boosted by sedimentation and an anaerobic metabolism. These are capable of producing effluents with a low BOD and nutrient concentration. The pond requires simple maintenance and can tolerate high hydraulic and organic shock loadings and heavy metals concentration up to 30 mg/l (Horan, 1991,Brock and Madigan, 1988). This is only feasible where land is freely available at reasonable cost.

Constructed wetland is a treatment method that incorporates a tolerant plant species that is locally available at minimal cost. It can either be free flowing or sub-surface flow in design with a slope (1-4%) to allow gravitational flow of leachates through the system. It may be constructed by having layers of gravel or crushed rock supporting a topmost layer of sand where the plants are growing. The unit may be subdivided into inlet zone, zone of actively growing plants and outlet zone. The inlet and outlet zones are filled with gravel for effective performance. The efficiency of treatment is attributed to the retention time (10-36 hours) and to the development of microbial film and its diversity, which mineralises and degrades leachate components to satisfy energy and biochemical requirements (Brock and Madigan, 1988; USEPA, 1992). Typical features of this system, according to Cooper et al (1989), are: the roots of the plants grow vertically and horizontally to provide maximum contact with the leachates and gravel media; effluents which are treated by aerobic biological activity at the rhizophere and inlet zone while anoxic and anaerobic treatment takes place at the middle and base of the system. Typical examples where constructed wetland technology is used to treat leachates is the Huneault landfill in Ontario, Canada (Sartaj et al, 1998). Constructed wetland technology offers an economic and sustainable solution for the treatment of leachates in developing countries where conventional treatment methods are hindered by finance,

To design a treatment process for the site, constraints such as lack of skilled personnel, a guaranteed source of power, facilities for plant operation and maintenance need to be considered. Therefore, typical methods of treatment that are sustainable, cost effective and feasible for such sites under the prevailing conditions are neutralisation, gravel filtration, stabilisation pond and application of

Table 5.0: Characteristics of Effluents obtained from some treatment methods and national regulatory standards in Nigeria.

Parameters	Leachates	Neutralization (Perchloric acid)	Gravel filtration	Constructed wetland	FEPA's standard
SS (mg/l)	197.5	146.5 (25.5)	53 (73.2)	37.5 (81.01)	30.0
BOD (mg/l)	712	424 (40.5)	166 (76.7)	99.5 (86.03)	50.0
Nitrate (mg/l)	1.06	1.21 (*14.2)	2.37 (*123.6)	3.67 (*246.2)	20.0
Phosphate (mg/l)	0.61	0.33 (44.5)	0.26 (56.3)	0.14 (76.5)	05.0
Lead (mg/l)	1.64	1.26 (23.4)	0.45 (72.5)	0.03 (97.93)	< 1
Iron (mg/l)	198.14	143 (27.8)	34.24 (82.61)	3.61 (98.18)	20.0

KEY: Values in parentheses are reduction in concentration of effluents in percentages.
* = Increase in concentration.

constructed wetlands, incorporating a locally available, leachate tolerant plant species.

The results obtained so far from some treatment methods (Table 5.0) showed that leachate management using a commonly found, leachate tolerant, aquatic plant (Ipomoea aquatica forsk) showed good reduction in effluent values and should be exploited for leachate treatment at the landfill site.

Conclusions

Solid waste management has been a very serious problem in urban centres. Wastes taken to a dumpsite for disposal yield leachates which cause serious problems through contaminating the land and water resources nearby. Developing countries like Nigeria have not been able to address these problems due to high costs involved. Thus, of the various solutions to this problem which are available, an aquatic plant, Ipomoea aquatica Forsk is found to reduce various organic and toxic pollutants to the desired levels. This plant is indigenous, tolerant to tropical climate and toxic chemicals. This phytoremediation technique can also be used in combination with other physico-chemical methods which prove to be viable and economic in keeping the environment safe.

Acknowledgements

We acknowledge the immense contribution of Mr. S. O. Oladoyinbo, Department of Chemical Pathology, University College Hospital, Ibadan and Mr. M.O Odusan, Department of Epidemiology, Medical Statistics and Environmental Health laboratory, University of Ibadan for their assistance.

References

Akinbiyi R. (1992) Improving the Urban Environment. Africa Health. Vol. 15, Number 1. pp. 26.

Aluko O.O (2001) Characterization and Treatment of Leachates from a Municipal Solid waste Landfill site in Ibadan. MPH Dissertation. University of Ibadan, Ibadan, Nigeria. 83-84.

Aluko.O.O, Sridhar, M.K.C and Oluwande P.A (2000) Treatment of Leachates from Municipal Solid Wastes using Constructed Wetlands: A Nigerian Experience. International Conference on Constructed Wetlands for Wastewater Treatment in Tropical and Sub-tropical Regions, India. 30.

APHA (1998) Standard Methods for Examination of Water and Wastewater. 19th edition, American Public Health Association, Washington, DC.

Brock T.D. and Madigan M.T. (1988) Biology of Microorganisms. 5th edition. Prentice Hall International inc. Pp. 641 - 644.

Campbell D.J.V. (1993). Environmental Management of Landfill Sites. J.I.W.E.M. Vol.7 No2. pp. 170 - 173.

Charlotte Y. (1998). Applying COSHH Principles to Waste Management. Environmental Health Journal. Vol. 106, No 10. Pp289 - 291.

Cooper, PF, Hobson, JA and Jones, S. (1989). Sewage treatment by reed bed systems. J.I.W.E.E.M Vol. 3. 60-74

Federal Environmental Protection Agency (FEPA) (1991). National Interim Guidelines and Standards for Industrial Effluents and Water Quality Tests. FEPA. Pp. 32 - 59.

Harrison, R.M. (1996). Pollution: Causes, Effects and Control. Third edition. The Royal Society of Chemistry. 340-365.

Horan, N.J. (1991). Biological Wastewater Treatment Systems: Theory and operations. John Wiley and sons. Pp. 309.

Loizidou, M. and Kapetanios, E.G. (1993) Effect of Leachate from Landfills on Underground Water Quality. The Science of the Total Environment. Vol. 128. Pp. 69 - 81.

Ogban, F E (2000). Industry and Water Pollution. Environmental News. Vol. 6. No. 1. Nigerian Environmental Society, Lagos, Nigeria. 18 – 24

Ojeshina, O.A. (1999) Sanitary and Hazardous Waste: Landfill as a Waste Disposal Strategy for Nigerian settlement. A paper presented at a one day workshop as part of the activities to mark FEPA's 10th year anniversary. 12pp.

Omisakin, MA and Sridhar, MKC (1986). Living near a refuse disposal site. Boicycle, 5. 50-51.

Peavy, S.H. Rowe, D.R. and Tchobanoglous, G. (1985) Environmental Engineering. McGraw-Hill Book Company. 573 - 652.

Sartaj, M; Fanandes, L. and Hulston, J.R (1998). Attenuation of Leachate Contaminants in an Engineered Wetland. In: Water Rock International. Proceedings of the 9th International Symposium, Taupo, New Zealand. (Arehart, G.B eds.). 1001-1004.

Speight, J.G. (1996). Environmental Technology Handbook: Applied Energy Technology series. Taylor and Francis. 302pp .

Sridhar, M.K.C.; Bammeke, A.O. and Omishakin, M.A. (1985). A Study on the Characteristics of Refuse in Ibadan, Nigeria. Waste Management and Research, Denmark. 3. 191 - 201.

Tairu, T.T (1998) Aspects of Environmental Impact Assessment of Solid Waste Disposal Sites in Ibadan. M.P.H. Dissertation, University of Ibadan. 59 - 63.

Taras, J.M (1950). Phenoldisulfonic Acid Method of Determining Nitrate in Water. Journal of Analytical Chemistry. Vol. 22. No. 8. 1020-1022.

UNCHS, (Habitat)/UNEP (1997). City Experiences and International Support. Vol. 2. 67-70.

USEPA (1992). Community water and wastewater tratment. Office of research and development, Washington, D.C. USEPA, 5-38

Vrijheid, M. (2000). Health effects of Residence near Hazardous Waste Landfill Sites: A Review of Epidemiological Literature. Environmental Health Perspectives Supplements. Vol. 8 No. 1. 101 - 112.

Waite, R. (1995) Household Waste Recycling. EARTHSCAN Publications Limited, London. 174.