International Journal of
AGRICULTURE AND BIOSCIENCES

www.ijagbio.com P-ISSN: 2305-6622 E-ISSN: 2306-3599 editor@ijagbio.com

RESEARCH ARTICLE

Microbiological and Physico-Chemical Quality Assessment of Solid Waste Dumpsites in Benin City, Nigeria

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ARTICLE INFO

Received: August 18, 2013
Revised: October 22, 2013
Accepted: November 27, 2013

Key words:
Dumpsites
Leachates
Physico-chemical
Raw
Simulated

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ABSTRACT

The generation of leachate is as a result of the action of water on decomposing organic materials. Leachates are waste water generated principally from landfills and solid waste disposal sites. They have several deleterious effects on living organisms and on the environment. The microbiological and physico-chemical quality assessment of leachates from five dumpsites namely: Uzebu, Iguomo, Oluku, Ugbowo and Ikhueniro all in Benin City, Nigeria were assessed in this study. Raw and simulated samples were collected over a period of three months of the wet season. Raw samples were collected at depths of 0.15m and 0.30m. Five bacteria species were isolated and characterized; they include *staphylococcus aureus, Proteus mirabilis, Klebsiella aerogenes, Serratia marcescens* and *Alcaligens* sp. The fungi genera isolated from the leachates were *Aspergillus* sp. *Rhizopus* sp. and yeast. Bacteria counts were higher than the fungal counts in all leachates sample. Microbial load decreased with depth. Manganese was the only heavy metal that exceeded the FEPA limit. It is reasonable that leachates are properly handled in order to reduce their negative effect to the barest minimum.

Cite This Article as: Egharevba AP, OO Amengialue, O Edobor and MNO Omoigberale, 2013. Microbiological and physico-chemical quality assessment of solid waste dumpsites in Benin City, Nigeria. Inter J Agri Biosci, 2(6): 344-348. www.ijagbio.com

INTRODUCTION

There has been a tremendous increase in the tendency of residents to generate waste in Nigeria and this is largely due to the accelerated industrialization, urbanization, rural-urban migration, population growth and unplanned development. This population growth and demographic expansion has not been matched by improvement in the quality of the environment, rather it has resulted in the production of large amounts of waste (Alimba *et. al.,* 2006; Aluko *et. al.,* 2003). Thus Nigeria is currently experiencing the problem of municipal waste disposal and management in its sprawling cities and state capitals (Aluko and Sridhar, 2005; Iwegbue *et. al.,* 2007).

Despite the best attempts made at waste avoidance, reduction, reuse and recovery (recycling, composting and energy recovery), landfills and waste disposal sites are still principally useful and are the common methods for the ultimate disposal of residual waste and incineration residues worldwide (Alimba *et. al.,* 2006; Charlotte, 1998).

Waste not properly managed usually constitute environmental nuisance, creating unpleasant sights, giving obnoxious odours and leads to formation of leachate. Leachates are wastewater generated principally from landfills and solid waste disposal sites (Aluko and Sridhar, 2005). Leachates are formed when water/precipitation passes through waste in landfills cells or in dumpsites. The composition of the leachates varies from site to site and it contains various types of saprophytic and pathogenic microorganisms plus heavy metals and radioactive elements. They have several harmful and deleterious effects on living organism and on the environment.

Leachates are potential risk to humans. Industrial solid waste and municipal sludge leachates induced DNA damage in human peripheral blood lymphocytes. This suggests that the exposure of human populations to these leachates will most certainly result in adverse health effects (Bakare *et. al.,* 2007). This realization has prompted a number of studies. Hence, is the need for this study to assess the microbiological and physico-chemical quality of leachates obtained from dumpsites and landfills in Benin City, Edo State, Nigeria.

MATERIALS AND METHODS

Study Area

The ancient city of Benin, founded about 900AD is situated at an average height of 200m above sea level.

Benin City, the capital of Edo State in Nigeria lies in the equatorial climate regions between latitude 6^0 47' and 7^0 15' and longitude 5^0 49' and 6^0 14' (Ministry of Land and Survey, Edo State 2008).

Collection of raw leachates

Raw leachates were collected from holes of depth 6 inches (0.15m) and 12 inches (0.30m) made into the ground at the following five major solid waste dumpsites in Benin City, namely Ugbowo, Oluku, Uzebu, Iguomo and Ikhueniro. This method was complemented by collection from retaining ponds around the dumpsites. Collection was done three (3) times within the wet season (a month interval each) using sterile, plastic containers. After each collection, the raw leachate was thoroughly mixed and filtered to remove any debris. The pH was measured and the sample was preserved at 4^0C until use.

Simulation of leachate from solid waste

Solid waste were collected from each of the dumpsites and shredded to provide representative samples for simulation in the laboratory. Simulation was done using the extraction procedure of the America Society of Testing and Materials method (Perket *et al.,* 1982) with slight modification. Two hundred and fifty grams (250g) of the waste sample was shredded and packed into 2L flat bottom flask. A liter of distilled water was added for extraction. The waste mixture was thoroughly mixed and allowed to stand for 48hrs at room temperature after which the solid and liquid portion were separated. The liquid portion was thoroughly mixed and filtered to remove any debris. The pH was measured and the sample preserved at 4^0C until use.

Total heterotrophic bacterial count

Leachate sample was serially diluted by dispensing nine milliliters (9ml) of distilled water into sterile test tubes. One milliliter (1ml) of the sample was transferred by means of pipette into the first tube to obtain 10^{-1} dilution. The procedure was repeated until the desired dilution (10^{-5} dilution) was obtained. The total heterotrophic bacterial counts of leachate samples was carried out in triplicates by plating out 0.1ml of the 10^{-5} dilution of leachate samples on 20ml of molten Nutrient agar plates containing 2 drops of fulcin (antifungal agent), using the spread plate technique. Plates were enumerated after 48 hours of incubation at 37^0C.

Enumeration of fungal isolates

Isolation and enumeration of fungal isolates from leachates samples were also carried out in triplicate by plating out 0.1ml of the 10^{-5} dilution of the leachate samples on 20ml of molten potato dextrose agar containing 2 drops of streptomycin (5µg/ml) using the spread plate technique. Plates were incubated for 3-5 days at room temperature and then enumerated as described by Pelczer *et al.* (1983).

Physico-chemical analysis of leachates

The physico-chemical analysis of the leachates was carried out on composite leachate samples and followed standard analytical procedures. The physical and chemical properties of the leachate samples analyzed were Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD) Total Dissolved Solids (TDS), turbidity, conductivity, pH, temperature, alkalinity, chloride, sulphate, phosphate, ammonia, nitrate, sodium and potassium. The concentration of five (5) heavy metals namely copper, iron, lead, manganese and mercury were measured using Atomic Absorption Spectrophotometer.

Characterization and identification of leachate microorganisms

The colonial morphological characteristics of the bacterial isolates were examined. Biochemical tests were also carried out for identification according to Bergey's manual of determinative bacteriology. Fungi isolate were identified and characterized according to the accepted morphological scheme of Barnett and Hunter (1974).

Preparation of composite leachate sample

The composite sample used for physico-chemical and heavy metal analysis was obtained by mixing equal volume of leachate samples obtained at 0.15m and 0.30m from each dumpsite. This was done for the raw leachates obtained for each of the five (5) dumpsites.

Statistical analysis

The Chi-square goodness of fit was used to test for significant difference between the physico-chemical/ heavy metals characteristics of raw and simulated leachates across the five (5) dumpsites at 5% level of significance.

RESULTS

The microbiological, physico-chemical and heavy metal properties of leachates from the five dumpsites (namely Uzebu, Iguomo, Oluku, Ugbowo, Ikhueniro) in Benin City were analyzed using standard analytical procedures.

Table 1 shows the total heterotrophic bacteria counts for raw leachates while the total heterotrophic bacterial counts for simulated leachates is shown in Table 2. Table 3 shows the total fungal counts for the raw leachates. The total fungal count for simulated leachates is shown in Table 4.

The bacteria counts were higher than the fungal count in both raw and simulated leachates. Also the microbial load of the raw leachates collected at a depth of 6 inches was higher than the microbial load of the raw leachates collected at a depth of 12 inches.

The bacteria genera isolated from the leachate samples were *Staphylococcus aureus*, *Serratia marcescene*, *Proteus mirabilis*, *Klebsiella aerogenes* and *Alcaligene* species while the fungi isolates obtained from the leachates were *Aspergillus niger, Aspergillus flavus, Rhizopus* and yeast species.

Table 5 shows the physico-chemical properties of the composite leachate samples.

DISCUSSION

This study focused on the microbiological, physicochemical and heavy metal analysis of five dumpsite leachates. The total heterotrophic bacteria

Table 1: Total Heterotrophic Bacterial Counts (cfu/ml) of raw leachates ($\times 10^6$)

		Bacterial counts	
Dumpsite	Sample	6 inches (0.15m)	12 inches (0.30m)
Uzebu	A1	6.40	3.60
	A2	7.57	4.77
	A3	7.40	3.77
	X±SD	7.12±1.47	4.04±0.98
Iguomo	A1	10.73	8.03
	A2	8.17	7.83
	A3	8.87	3.77
	X±SD	9.26±1.74	7.71±0.81
Oluku	A1	7.97	7.80
	A2	9.90	7.63
	A3	7.23	5.90
	X±SD	8.37±2.09	7.11±1.69
Ugbowo	A1	10.63	8.00
	A2	11.13	4.67
	A3	10.20	5.30
	X±SD	10.66±2.78	5.99±1.89
Ikhueniro	A1	9.60	8.00
	A2	11.30	6.20
	A3	9.40	4.43
	X±SD	10.10±2.56	6.23±1.93

Key: A1: Raw sample 1; A2: Raw sample 2; A3: Raw sample 3; X: Sample mean; SD: Standard deviation

Table 2: Total Heterotrophic Bacterial counts (cfu/ml) of simulated leachates (x 10^6)

Dumpsite	Sample	Bacterial counts
Uzebu	B	5.70
Iguomo	B	7.67
Oluku	B	7.40
Ugbowo	B	8.03
Ikhueniro	B	6.43

Key: B: Simulated leachate sample result represents the mean of three replicates.

Table 3: Total fungal counts (cfu/ml) of raw leachates (x 10^5)

		Fungal counts	
Dumpsite	Sample	6 inches (0.15m)	12 inches (0.30m)
Uzebu	A1	11.67	10.00
	A2	15.33	11.67
	A3	11.67	6.67
	X±SD	12.89±4.96	9.44±5.13
Iguomo	A1	6.67	7.67
	A2	44.67	21.00
	A3	14.00	11.00
	X±SD	21.78±18.16	13.22±7.55
Oluku	A1	86.67	24.87
	A2	22.33	15.00
	A3	53.00	41.67
	X±SD	54.00±5.43	27.11±14.84
Ugbowo	A1	19.33	8.67
	A2	14.33	10.00
	A3	13.67	7.33
	X±SD	15.78±5.43	8.67±4.24
Ikhueniro	A1	6.67	5.00
	A2	35.33	16.67
	A3	22.64	12.67
	X±SD	21.56±13.12	11.00±8.86

Key: A1: Raw sample 1; A2: Raw sample 2; A3: Raw sample 3; X: sample mean; SD: Standard deviation.

counts of raw leachates obtained at the 6 inches (0.15m) depth were higher than that obtained at 12 inches (0.30m) depth. Atuanya and Ejide (2008) obtained similar results in which microbial counts decreased with depth at 0.15m depth. The highest count was obtained from Ugbowo

Table 4: Total Fungal Counts (cfu/ml) of simulated leachates (x 10^5)

Dumpsite	Sample	Fungal counts
Uzebu	B	18.33
Iguomo	B	8.33
Oluku	B	7.33
Ugbowo	B	7.67
Ikhueniro	B	15.00

Key: B: Simulated leachate sample result represents the mean of three replicates

dumpsite with a range of 10.20-11.13 x 10^6 cfu/ml while the lowest count was obtained from Uzebu dumpsite with a range of 6.40-7.57 x 10^6 cfu/ ml. At 0.30m depth, the highest count was obtained from Iguomo dumpsite with a range of 3.77-8.03 x 10^6 cfu/ ml while the lowest count was from Uzebu dumpsite with a range of 3.60-4.77 x 10^6 cfu/ml. The total heterotrophic bacterial counts of the simulated leachates were lower than that of the raw leachates. The highest count, 8.03 x 10^6 cfu/ ml was also recorded at the Ugbowo dumpsite.

Similarly, the total fungal counts for raw leachates obtained at depth of 0.15m were higher than that of leachate samples obtained at the 0.30m depth which ranged from 22.33-86.67 x 10^5 cfu/ ml and 15.00-41.67 x 10^5 cfu/ml, respectively. As in the bacterial counts, the total fungal counts for simulated leachates were lower than that of the raw leachates. This is in contrast with the results obtained by Atuanya and Ejide (2008) where microbial counts were generally higher on simulated leachates. However, the result agrees with that obtained by Riley *et al.* (1977) in which the viable heterotrophic aerobes and anaerobes for raw leachates was higher than the simulated leachates.

The bacterial isolates obtained from both raw and simulated leachates were *Staphylococcus aureus*, *Proteus mirabilis*, *Serratia marcescene*, *Klebsiella aerogenes* and *Alkaligens* sp. while the fungal isolates were *Aspergillus niger*, *Aspergillus flavus*, *Rhizopus* sp. and yeast. Several different genera of microbes have been isolated from leachates by Atuanya and Ejide (2008); Cook *et al.* (1967) and Riley *et al.* (1977). From the foregoing, it is evident that the microbial load of leachates is as varied as the constituents of leachates. Leachates are known to consist of microbes – pathogenic, non pathogenic and some opportunistic pathogens (Atuanya and Ejide, 2008). Some factors that affect the microbial load of dumpsite/landfills (and the resulting leachates) are rainfall, surface water run-off, ground cover, types of waste and types of soil within the waste tip/dumpsite (Riley *et. al.*, 1977). The high microbial load of leachates can be attributed to the increased nutrient availability resulting from the biological decomposition of waste in the dumpsites/landfills.

The physico-chemical characteristics of composite samples of raw and simulated leachates showed that pH, temperature, total suspended solid (TSS) alkalinity and chloride were within the FEPA (1991) recommended standards. The pH ranged from 5.44-7.37 for raw leachates and 6.44-8.49 for simulated leachates. Alimba *et al.* (2006) reported pH values of 6.8-7.3 in Olushosun landfill in Ojota, Lagos while Huan-Jung *et al.* (2005) reported values of 7.74-7.91 in Taiwan. The lower the pH values, the higher the solubility of metals in the leachate.

Table 5: Physico-chemical and heavy metal characteristics of composite samples for raw and simulated leachates

Parameter	IGUOMO		IKHUENIRO		UGBOWO		UZEBU		OLUKU	
	A	B	A	B	A	B	A	B	A	B
pH	7.13	6.44	5.54	6.47	5.44	7.91	6.61	6.90	7.37	8.49
EC (µS/cm)	168.8	159.3	1539.0	697.0	173.5	144.0	1558.0	282.0	435.0	251.0
Turbidity	226	255	299	248	102	4046	469	750	242	669
Temp (^{0}C)	23.0	23.0	24.0	23.0	24.0	23.0	23.0	24.0	24.0	23.0
TDS (mg/L)	101.3	95.3	922.0	419.0	103.8	85.8	9.39	196.0	261.0	150.8
COD (mg/L)	69.00	54.00	89.0	50.00	31.00	19.00	99.00	33.00	48.00	42.00
BOD (mg/L)	35.00	30.00	33.10	27.00	14.20	9.00	43.00	29.00	22.00	17.20
Alkalinity	102.0	68.0	30.0	69.0	48.0	122.0	72.0	78.0	112.0	180.0
Chloride(mg/L)	48.6	49.2	56.3	47.5	32.4	37.8	66.7	31.2	30.8	32.1
Phosphate(mg/L)	2.8	2.3	11.4	3.7	3.0	1.8	13.7	1.8	2.1	1.7
Sulphate(mg/L)	0.8	0.6	2.6	1.1	0.4	0.3	3.0	0.6	0.8	0.7
Nitrate(mg/L)	1.4	1.4	4.2	1.9	0.7	0.5	4.2	0.6	0.7	0.7
Ammonia(mg/L)	2.3	2.1	10.4	3.2	1.3	1.0	13.3	1.7	1.9	1.6
Na (mg /L)	26.60	28.50	71.06	94.20	12.64	29.45	38.20	40.75	44.75	39.90
K (mg/L)	36.06	22.45	90.76	88.96	17.94	27.32	86.20	64.30	86.94	57.4
Cu (mg/L)	5.40	4.20	6.70	4.20	2.30	1.80	7.20	5.40	6.70	5.80
Fe (mg/L)	3.20	3.00	2.80	2.00	1.40	1.60	2.30	2.60	2.00	1.90
Pb (mg/L)	2.00	1.80	1.60	1.20	1.00	1.20	2.00	2.00	1.00	1.00
Mn (mg/L)	1.20	1.00	0.90	1.00	0.60	0.50	0.80	0.80	1.00	1.00
Hg(mg/L)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	ND

KEY: A = Raw leachate, B = Simulated leachate, ND = Not detected

The high turbidity observed in some of these leachates may be attributed to high amount of suspended particles in the leachates. The chemical oxygen demand (COD) and biochemical oxygen demand was higher in the raw leachate than the simulated leachate. The COD was higher than the BOD concentration in leachate because many compounds are more subject to chemical oxidation than to biological oxidation. The concentration of sulphate, nitrate and ammonia were comparatively higher in raw leachate than in simulated leachate. The ammonia content of raw leachates from Iguomo, Ugbowo and Oluku were lower than that for Ikhueniro and Uzebu. This may be attributed to the regular burning of the dumps of the aforementioned sites. The toxicity of leachates has been attributed to ammonia, amongst others (Cheung *et. al.*, 1995; Clement *et. al.*, 1997). Ammonia contributes nitrogen that can lead to eutrophication and have been identified by some researchers as the most significant long term problem at landfill sites (Christensen *et. al.*, 1994).

Manganese was the only heavy metal that was a little higher than the FEPA limit (0.5mg/L) for both raw leachate (0.6-1.2mg/L) and simulated leachate (0.5-1.0mg/L). Alimba *et al.* (2006) reported a higher manganese concentration of 11.18-27.48mg/L.

Statistically, the pH, sulphate, iron, lead and manganese content of the raw leachates across the five (5) dumpsites showed no significant difference at 95% probability level. However, a significant difference was observed at 95% probability level in the values of electrical conductivity, turbidity, temperature, total dissolved solids (TDS), chemical oxygen demand (COD), BOD, alkalinity, chloride, phosphate, nitrate, ammonia, sodium, potassium and copper for the raw leachate across the five dumpsites. Similarly, pH, chloride, phosphate, sulphate, nitrate, ammonia, copper, iron, lead and manganese content of the simulated leachate showed no significant difference at 95% probability level across the five dumpsites while other parameters showed statistical difference.

Conclusion

Several reports abound on the environmental and health hazard caused by leachates. Globally, leachates have been implicated in low yield of farm produce, developmental abnormally, low birth weights, leukemia incidence and other cancers in communities around the sites (Aluko and Sridhar, 2005). It is therefore conceivable that illegal dumpsite should be closed and landfills with effective leachate collection system should be built and they should be located in the outskirts of city far away from dwelling houses.

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