

ENVIRONMENTAL AND PUBLIC HEALTH ASPECTS OF SOLID WASTE MANAGEMENT AT THE LEMNA DUMPSITE IN CALABAR, CROSS RIVER STATE, NIGERIA

ABSTRACT

This study is aimed at investigating the level of environmental pollution and the potential impacts of municipal solid wastes on public health. The health risk assessment was determined through a survey of the present facilities used for solid waste management in the metropolis. Waste bins, types of depots, modes of transportation of wastes to disposal sites and methods of disposal were amongst the facilities investigated. The microbiological and physicochemical analysis of decomposing solid waste, leachate, soil, air at dumpsite, stream and Ikot Effanga Mkpa river waters were carried out using standard microbiological procedures. The prevalent bacteria besides fungi isolated from decomposing solid waste, soil, leachate, stream and river water samples were *Escherichia coli* 55(13.31%) and 48 (14.33%) *Chromobacterium spp* 36 (18.18%), *Staphylococcus spp* 37(17.70%), *Salmonella spp* 45(16.85%) and *Klebsiella spp* (17.06%) respectively. Statistical analysis of the bacterial and fungal counts showed significant difference ($p<0.05$) between the sources of sampling, months of sampling and seasons of sampling. Decomposing solid wastes followed by soil and leachate had the highest counts at 5% level of probability. The high bacterial counts coupled with these findings are indicative of the possible high risk of microbial infections and a potential destruction of biodiversity from the toxic chemicals of the wastes. The results of the physicochemical analysis showed that virtually, most of the parameters determined are above the WHO permissible limits for drinking water. It is recommended that a fit for purpose strategy be developed for waste management with control measures that are health and eco-friendly.

KEY WORDS: Municipal solid wastes, public health implications, lemna dumpsite, leachates, pollution.

INTRODUCTION

Municipal solid wastes (MSW) constitute environmental and public health hazards all over the world. Hence, the management of solid waste is a vital tool for the enhancement of social services whose budget and provisions are made in line with population projection. Solid waste management in its entire ramification is a planned system of effectively controlling the production, storage, collection, transportation, processing, and disposal or utilization of waste in a sanitary aesthetically economical manner that is in accordance with the best principles of public health. This of course includes all administrative, financial, legal planning functions as well as the physical aspects of waste handling (Asikong and Udofia, 2005).

44 Solid wastes that constitutes nuisance to the environment consist of
45 household waste, construction and demolition debris of residence and street
46 wastes generated from residential and commercial complexes. Garbage has
47 often originated enormously from the rapid urbanization, changes in the life
48 style and food habits, resulting in increase in the amount and types of solid
49 waste (Atlas and Bartha, 1992). Unfortunately, the ability to manage such
50 enormous waste is beyond the resources of most administrations in developing
51 countries (WHO, 2007; Anija-Obi *et al.*, 2001; Khupe, 1996; Yaliang, 1996).

52 Sanitation geared towards environmental friendliness is the essence of
53 municipal solid waste management and disposal of waste. The main aim of
54 waste treatment and safe disposal is to exclude pathogens, germs, vectors and
55 diseases such as rats, cockroaches, mosquitoes, particulate matter, hazardous
56 chemicals e.g. petrol, spirits, syringes from hospitals, radioactive
57 substances, drugs and heavy metals. Therefore, it is of utmost importance that
58 each stage of solid waste management be technically planned in a manner to
59 avoid environmental and public health hazards listed above (Feachem *et al.*,
60 1983).

61 PAI Associate International (1982), reports that little or no attention has
62 been given to ensuring that households in Nigeria play their part effectively in
63 the organization of solid wastes storage, collection and disposal. It also reports
64 that only a few cities like Jos in Nigeria have bye-law that is rigorously
65 enforced as they specify dustbins for households (PAI Associate International,
66 1982).

67 However, in the developed countries of the world, greater concern is on
68 the development of an ecologically sound and health-promoting ways of
69 managing the millions tons of urban wastes that are generated daily. In the
70 western world, each household produces approximately one ton of solid waste
71 per year. The vast waste produced from Agriculture, industries, mining and
72 commerce are not included.

73 Waste management and disposal techniques in Nigeria needs urgent
74 attention. A number of solid waste management companies and authorities in
75 Nigeria still do not adopt the sanitary landfill/controlled tipping method that
76 allows the waste to be dumped in accordance with best principles of public
77 health and the environment. Here the wastes are compacted and covered in
78 trenches at the end of each day. If waste is dumped in an uncontrolled manner, it
79 often consumes much space and may be a breeding ground for rodents, insects;
80 and leachates may also contaminate underground water as they seep down.

81 In most part of the world, there are regulations that govern where a
82 landfill (Sanitary landfill) can be placed and how it can operate the whose
83 process begins with a proposal for the site followed by an environmental impact
84 assessment of the site to determine that the area of land is necessary for the
85 proposal landfill, the composition of the underlying soil and bedrock, the
86 historical or archaeological value of the proposed site and the potential effects

of the landfill and possible contamination on local wildlife. This is often preceded by a permit from the local, state and federal government authorities to kick start the operation. The choice for sanitary landfill by most developed countries on proper environmental impact assessment is based on the fact that it is environmental friendly and does not contaminated both the underground water and the environment. It is on record that most Nigerian cities including Calabar uses open dump system of waste disposal (PAI Associate, 1982). For instance, Lemna dumpsite in Calabar metropolis is an on open dump with no control of rodents, flied and other pollutants, thus posing environmental and public health consequences such as underground water and soil contamination by toxic metals, aesthetic nuisance, air pollution, surface water contamination, noxious odours and often times, a suitable breeding ground for mosquitoes, flies, rodents, snakes and pathogenic microorganisms.

The study was undertaken at Lemna dumpsite to assess the level of environmental pollution and the potential impacts on public health in relation to solid waste management in Calabar Metropolis, the capital of Cross River State, Nigeria. Calabar metropolis whose current population is about 371,022,000 is situated between latitude 4°57'N and longitude 8°20E (Figure 1).

MATERIALS AND METHODS

Health Risk Assessment of Solid Waste Management in Calabar

In order to assess the health risk of solid waste management in Calabar metropolis, a survey was undertaken to find out the existing facilities used for the management of solid waste. The facilities include; waste bins available at residential areas, markets, industrial and office places; types of depots if present; mode transportation of waste to the disposal dumpsite (if landfill).

Soil Sample Collection

A garden rake was used to remove the waste to expose the soil beneath the waste dump from where the soil samples were collected. The soil samples were taken at 15cm and 30cm depth with the use of a hand-driven auger and then taken to the laboratory in labeled sterile Petri-dishes seated with masking tape and foil in ice-cold boxes at approximately 4°C for both microbiological and physicochemical analysis.

Figure 1: Calabar Municipality area showing study site
Source: GIS Unit, University of Calabar, 2012



PLATE 1: Lemna solid waste dumpsite

Decomposing Solid Waste Sample Collection

A previously sterilized large wooden spatula rinsed with sterile, distilled water was used to collect the decomposing solid waste samples into sterile Petri dishes, sealed with masking tape and foil, and properly labeled as DSW₁, DSW₂, DSW₃, and DSW₄ to indicate the sampled points at the Ikot Effanga Mkpa dumpsite. The samples are transported to the laboratory in ice-cold boxes for microbiological and physicochemical analysis or store at 4°C until they were needed for analysis.

Leachate Sample Collection

PVC pipes were bought and cut into four parts, each of 1.0-1.5 length. The base end of each pipe was permanently sealed with a pipe cover and an adhesive while the top ends were just fitted with pipe covers. The pipes (both 1m and 0.5m length) were perforated evenly at considerable distances from their base ends to allow for water percolation and collection. The whole pipe lengths were then buried into an already dug ground in each sampling point with small allowances at the top for access to top ends (which were only temporarily sealed). The dug out soil and wastes were replaced back to the ground and made to properly cover the pipes. This was left for a period of three to four (3-4) weeks before sampling for the percolated leachates. Sterile enema pumps were used for the leachate collection into sterile bottles and labeled properly as L₁, L₂, L₃ and L₄ respectively. The samples were then taken to the

laboratory for microbiological and physicochemical analysis or stored in the refrigerator maintained at 4⁰C until required for analysis.



A



B



C



D

PLATE 2: (A) Perforated PVC pipes used for sampling of leachates from the dumpsite (B) perforated PVC pipe buried at Lemna Dumpsite (C) control PVC pipe buried 500m away from Lemna dumpsite (D) Buried perforated PVC pipe filled with leachates after three(3) weeks.

Water Sample Collection from Ikot-Effanga Mkpa Stream and River

Water samples were collected from Ikot-Effanga Mkpa stream and River into which run-off from the dumpsite flows and labeled as SW₁, SW₂, SW₃, SW₄, and RW₁, RW₂, RW₃, RW₄ respectively. For both stream and river, the locations sampled consisted of two upstream and two downstream points. The waters samples were collected using standard procedures and precautions into previously sterilized containers and transported to the laboratory in an Ice-cold boxes for microbiological and physicochemical analysis or stored at 4°C in a refrigerator until needed for analysis.

Bacteriological Analysis of Soil, Decomposing Solid Waste and Water Samples

One gram (1g) of the soil was dissolved in 9ml sterile distilled water. The solution was then used to make ten-fold serial dilutions in the range of 10⁻¹-10⁻⁹ (Etok *et al.*, 2004; Atlas and Bartha, 1992). One milliliter (1ml) of the sample dilution from 10⁻⁴-10⁻⁷ was then seeded into sterile Petri dishes and total bacterial count was determined by pour plate technique using tryptone soya Agar that can support the growth of aerobes and anaerobes (Eja, 2010). Tryptone soya agar supplemented with 1% (w/v) of cysteine hydrochloride (BDH chemicals, U.K.) used for the isolation of anaerobes while tryptone soya was used for the isolation of aerobes. All aerobic cultures were incubated at ambient temperature that fluctuates between 25-28°C, for 48 hours, while anaerobic cultures were incubated in a Baird and Tatlock anaerobic jar at 30°C for 48 to 72 hours. The visible growth (colonies) between 30 and 300 were multiplied by the reciprocal of the dilution pactors and recorded as colony forming units per gram (cfu/g) of the waste (Etok *et al.*, 2004; Asikong and Udofia, 2005). Same treatment was given to decomposing solid waste (DSW), Ikot Effanga Mkpa stream and river water samples. Each of the dilution (10⁻⁴-10⁻⁷) was cultured in triplicate to determine the mean counts. The colonies growth from the tryptone soya agar were picked using a sterile wire loop and

streaked on nutrient agar and incubated at 37°C for 24hours. This was repeated several times to obtain pure culture of bacterial isolates. The distinct colonies were then subcultured into nutrient agar slants and stored in the 4°C refrigerator until required for characterization.

Total Fungal Counts

Same procedure adopted for bacterial was used for fungal counts for both the decomposing solid waste and soil samples. The only difference was the media used which was sabouraud dextrose agar supplemented with 100µg of streptomycin and 15µg of nystatin to inhibit bacterial growth. The plates were incubated for 3-5 days at room temperature. The characteristic colonies were sub-cultured on malt extract agar (oxoid), acidified to pH of 4.8 to suppress the growth of bacteria and obtain pure cultures of fungal isolates. The isolates were identified using standard identification procedures (Asikong *et al.*, 2013).

Microbiological Analysis of Air at Dumpsite

Settle plates method described by Eja, (2010) was used for the analysis. Nutrient agar plates in triplicate were exposed at the dumpsite (10m, 20m, 30m and 100m) away from the dumpsite for an hour between 10AM and 12PM. The plates were then covered after 1 hour and transported to the laboratory for incubation at 25-28°C for 24 hours. The bacterial colonies that appeared on the plate were counted. The counts on plate placed at 10m and 100m away from the dumpsite were compared to give an insight on the level of air pollution.

Microbiological Analysis of Leachates

Leachates from such dumpsites are often turbid, therefore, serial ten-fold dilutions were made in the range of 10^{-1} - 10^{-9} . One millilitre was dissolved in 9 millilitre of sterile distilled water to give 10^{-1} dilution, followed by 10^{-2} upto 10^{-9} . Same analysis given to soil and decomposing solid waste was adopted for the leachate and the counts obtained expressed as colony forming units per millilitre

of leachate (cfu/ml). same purification procedures was used as that of soil and decomposing solid waste isolates.

Characterization and Identification of Purified Microbial Isolates

Pure cultures of the isolates were inoculated onto nutrient agar to obtain purer isolates. MacConkey agar was used for the isolation of coli-aerogenes-like enteric microorganisms (Etok *et al.*, 2004) Xylose Lysine Deoxychocolate (XLD) agar was used for the presumptive identification of both *Salmonella* and *Shigella* and are incubated at 37°C for 24 hours (Etok *et al.*, 2004). On the MacConkey agar, *Escherichia coli* colonies appeared red and non-mucoid; *Aerobacter aerogenes* colonies appeared pink and mucoid; *Enterococcus faecalis* appeared red, minute and round; *Staphylococcus* colonies appeared pale-pink and opaque, while *Pseudomonas* colonies appeared brown with fluorescent growth (Holt *et al.*, 1994). On XLD agar, *Shigella* formed red colonies as they can ferment xylose, lactose or sucrose (Holt *et al.*, 1994) *Salmonella* also formed red colonies. *Proteus* strains formed red colonies with black centres (Monica, 2005). The purified isolates were characterized using Bergey's manual of determinative bacteriology (Holt *et al.*, 1994).

Physicochemical Analysis of Soil and Decomposing Solid Waste

Moisture content of the soil was determined by determining the differences in weight before and after drying the soil in an oven at 120°C to constant weight. The soil samples were then and dried, ground with wooden roller and sieved through a 2mm mesh. pH was determined using pretreated soil samples mixed with distilled water in the ratio of 1:2 (w/v) using the Jenway pH meter models 5 (Eno *et al.*, 2009). The method described by Ekpo and Ibok (2000) used for the determination of organic carbon and available phosphorus. Ammonium (NH_4^+) was determined by measuring the NH_3 liberated action of (MgO) with NH_4^+ in the soil extract. Nitrite was determined

spectrophotometrically by the diazotization method as nitrate after reduction in a cadmium reduction system (Eno *et al.*, 2009). Total hydrocarbon (THC) measured followed extract with redistilled n-hexane before determining the total hydrocarbon content colorimetrically at 430nm using a DR/3000 HACH spectrophotometer (Loveland Colorado). Particle size was done by the Bouyoucos hydrometer method (Zach *et al.*, 2000) as modified by Gee and Bauder (1986). Total nitrogen was done using the Micro-Kjeldahl digestion method (Eno *et al.*, 2009).

All the decomposing solid waste samples were air-dried as was the case with soil, followed by grinding with a wooden roller and sieved with a 2mm mesh. Total organic carbon, electrical conductivity, available phosphorus, pH total hydrocarbon, potassium, calcium, sodium and magnesium were determined using the same procedures for analyzing soil samples.

Physicochemical Analysis of Ikot-Effanga Mkpa Stream/River Water

The pH, dissolved oxygen (DO₂) conductivity and water temperatures were determined at the site of sampling (Lemna dumpsite). Water temperature and dissolved (DO₂) were measured using JEWWAY 970 DO₂ meter with sensitivity of $\pm 0.1\%$. Salinity was measured using the Argentometric method. Turbidity (NTU) BOD₅, nitrite, (NO₂⁻) nitrite (NO₃⁻), chloride (CL⁻) and (SO₄²⁻) were determined using same procedures described for the leachates analysis.

Physicochemical Analysis of Leachates

Turbidity was determined spectrophotometrically using standards according to HACH. Biochemical oxygen demand (BOD₅) was determined as the difference between the initial oxygen concentration in sample and concentration after 5 days incubation in DO at 20°C (APHA, 1998). Nitrite and nitrate were measured spectrophotometrically by turbidometry using barium chloride (APHA, 1998). Total hydrocarbon was determined as described in soil

analysis. Chloride was determined titrimetrically using silver nitrate and potassium dichromate as indicator (Eno *et al.*, 2009). Temperature was determined using the Celsius thermometer.

Physicochemical Analysis for Heavy Metals in Leachate and Water

Using appropriate salts of the metal (Cr, Cd, Zn, Ni, Pb, Co, Mn, Cu, and Fe) the concentration of each metal in leachate were measured from the sample after due calibration runs using atomic absorption spectrophotometer (AAS Model 2380) (Rorrer, 1999).

STATISTICAL ANALYSIS

Statistical analysis using factorial experiment (ANOVA) was used to determine the association between the months of January to March, June to August on the one hand, and sources of samples on the other with respect to mean bacterial and fungal counts obtained.

RESULTS

The operational factors of solid wastes with much concern on public health are presented in Table 1. The results obtained shows the various sources of solid waste generated in Calabar metropolis, with emphasis on whether the households that generate the waste possessed dustbins or not and whether the waste generated were sorted out or not before they were transported to the disposal site. The survey also indicate that the mode of collection, transportation, disposal method and treatment of the solid waste generated do not conform to the safe principles of public health, except that the wastes transported to the dumpsite in trucks were covered with tarpaulin to reduce aerial contamination.

Table 2 shows the mean total bacterial counts of Ikot–Effanga Mkpa soil, decomposing solid waste (DSW), leachate, Ikot Effanga Mkpa stream and river samples during the dry season of January – March, 2011. The results obtained from the bacteriological examination of the decomposing solid wastes showed that decomposing solid waste (DSW) location A had the highest bacterial counts of $23.4 \pm 3.39 \times 10^6$ cfu/g for January, $20.9 \pm 5.44 \times 10^6$ cfu/g for February and $20.9 \pm 2.24 \times 10^6$ cfu/g for March ($P < 0.05$), while location D had the lowest bacterial counts of $10.7 \pm 1.69 \times 10^6$ cfu/g for January, $9.4 \pm 1.69 \times 10^6$ cfu/g for February and $15.3 \pm 2.87 \times 10^6$ cfu/g ($P < 0.05$) for March respectively.

In soil samples, location B had the highest bacterial counts of $8.7 \pm 2.16 \times 10^6$ cfu/g for January, $16.6 \pm 1.25 \times 10^6$ cfu/g for February and $16.3 \pm 2.16 \times 10^6$ cfu/g for March ($P < 0.05$). However, location D which was used as the control location for the three months of sampling had the lowest bacterial counts of $5.4 \pm 1.63 \times 10^6$ cfu/g for January, $9.7 \pm 1.69 \times 10^6$ cfu/g for February and $9.8 \pm 1.25 \times 10^6$ cfu/g for March ($P < 0.05$). For leachate samples, location C had the highest bacterial counts of $8.6 \pm 1.26 \times 10^6$ cfu/ml in January, $11.4 \pm 3.27 \times 10^6$ cfu/ml in February and $14.4 \pm 1.25 \times 10^6$ cfu/ml in March counts ($P < 0.05$), while leachate from location D had the lowest counts of $5.6 \pm 1.25 \times 10^6$ cfu/ml in January, $8.7 \pm 1.69 \times 10^6$ cfu/ml in February and $6.7 \pm 1.25 \times 10^6$ cfu/ml in March ($P < 0.05$).

377 **Table 1: Operational factors of solid waste management in Calabar metropolis which relate to public health**

S/N	Sources	Possession Sorted	Description of waste	Mode of transportation	Disposal method
1.	Residential institutions, hotels, stores, restaurants, market.	70% of population	Wastes from preparation, cooling and serving of food mainly, garbage.	Vehicular with wastes covered with tarpaulin ten ton tippers mostly used.	Open dumping into ravine and sometimes covered with top soil.
2.	Municipal, e.g. streets, sidewalks and alleys.	Sometimes depots are provided	Wastes are bulky. Mainly street refuse, dead animals and abandoned vehicles	Vehicular	Open dumping into ravine.
3.	Industrial, e.g. factories, power plants, sewage treatment plants, septic tanks, sites, vacant plots.	100% of the industrial	a. Industrial refuse from industrial processes and manufacturing operations such as food processing wastes, wood, plastic and metal scraps, etc. b. Construction and demolition wastes e.g. lumber, roofing and sheathing scraps, broken concrete etc. c. Sewage treatment residues, coarse screening, grit, dewatered sludge, septic tank sludge. d. Animal and agricultural	Vehicular	Open dumping into ravine.

			wastes such as manures and crop residues. e. Special wastes, mainly hazardous wastes such as pathological wastes, explosive, radioactive materials, security wastes, confidential document and papers.		
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378 * Certain objects, notably cans, fetal objects and bottles not to be allowed in the refuse bag and must be presented for collection:

379 NS = Not Sorted.

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Table 2: Mean bacterial counts of Lemna dumpsite in dry season

Location and sources of sample	January	February	March
Soil samples*			
Location A	6.3 ^c ±2.45	12.7 ^b ±1.25	15.4 ^a ±3.29
Location B	8.7 ^b ±2.16	16.6 ^a ±2.62	16.3 ^a ±0.82
Location C	5.4 ^c ±1.63	14.4 ^a ±2.16	13.4 ^b ±1.69
Location D	4.7 ^b ±1.25	9.7 ^a ±1.69	9.8 ^a ±1.25
Leacheate samples*			
Location A	6.1 ^c ±1.25	9.7 ^b ±1.69	12.3 ^a ±2.16
Location B	7.2 ^b ±2.16	9.3 ^a ±2.05	7.2 ^b ±0.82
Location C	8.6 ^c ±1.26	11.4 ^b ±3.27	14.2 ^a ±1.25
Location D	5.4 ^c ±1.25	8.7 ^a ±1.69	6.7 ^b ±1.25
IkotEffangaMkpastream*			
1 st downstream sample A	6.7 ^c ±0.95	9.7 ^b ±1.25	17.4 ^a ±0.25
2 nd downstream sample	5.7 ^c ±2.16	8.2 ^b ±1.69	16.3 ^a ±1.25
3 rd upstream sample C	5.2 ^c ±2.49	7.1 ^b ±1.25	16.7 ^a ±1.63
4 th upstream sample D	4.4 ^c ±2.05	5.9 ^b ±0.47	15.1 ^a ±1.25
Ikot Effanga Mkpapa river*			
1 st Upstream sample A	5.4 ^b ±3.29	5.6 ^b ±2.05	7.4 ^a ±2.62
2 nd Upstream sample	5.3 ^c ±0.82	6.6 ^b ±1.96	7.3 ^a ±3.56
3 rd downstream sample	9.4 ^c ±1.69	6.7 ^b ±1.69	9.5 ^a ±0.82
4th downstream sample D	4.7 ^b ±0.16	5.4 ^a ±3.68	5.5 ^a ±1.69
Decomposing Solid Waste*			
Location A	23.4 ^a ±3.39	20.9 ^b ±5.44	20.9 ^b ±2.24
Location B	10.8 ^b ±0.82	18.7 ^b ±1.69	18.5 ^a ±2.87
Location C	10.7 ^c ±1.69	11.7 ^b ±1.69	15.6 ^a ±2.62
Location D	10.7 ^b ±1.69	9.4 ^c ±1.69	15.3 ^a ±2.87

*Bacterial counts are expressed as counts (x10⁶cfu/g). Data are expressed as mean ± standard deviation of triplicate trials. Values with different superscripts (a,b,c) across each row are significant (P<0.05)

Table 3: Mean bacterial counts of Lemna dumpsite in wet season

Sources of samples	June	July	August
Soil sample *			
Location A	3.1 ^c ±0.82	4.0 ^b ±1.63	6.5 ^a ±2.45
Location B	3.2 ^c ±2.05	4.6 ^b ±1.63	7.4 ^a ±1.69
Location C	6.3 ^c ±3.74	6.3 ^b ±2.40	8.3 ^a ±1.69
Location D	3.7 ^c ±2.05	6.3 ^a ±1.24	5.7 ^b ±2.16

Leachate sample *			
Location A	4.3 ^c ±1.25	6.4 ^a ±3.29	5.7 ^b ±3.29
Location B	6.2 ^c ±2.05	6.4 ^b ±1.69	7.2 ^a ±2.05
Location C	5.1 ^b ±2.49	5.1 ^b ±0.94	6.4 ^a ±2.94
Location D	4.0 ^b ±1.41	4.2 ^b ±2.62	4.6 ^a ±2.45
DSW Sample *			
Location A	5.8 ^c ±3.68	7.2 ^b ±1.29	7.4 ^a ±3.39
Location B	5.4 ^b ±1.69	6.4 ^a ±1.69	6.4 ^a ±2.62
Location C	5.1 ^c ±2.49	6.3 ^b ±2.45	6.5 ^a ±2.45
Location D	4.6 ^c ±1.63	5.1 ^b ±1.73	6.4 ^a ±3.29
Ikot Effanga Mkpa*			
1 st Upstream sample A	3.6 ^c ±7.25	4.3 ^b ±2.10	6.3 ^a ±2.16
2 nd Upstream sample B	4.1 ^c ±2.05	5.2 ^b ±1.41	6.4 ^a ±2.05
1 st Upstream sample C	4.6 ^c ±1.63	6.6 ^b ±2.40	7.5 ^a ±2.05
2 nd Upstream sample D	4.4 ^c ±0.82	5.2 ^b ±1.63	6.4 ^a ±2.62
Ikot EffangaMkpaRiver*			
1 st Upstream sample A	3.2 ^c ±1.63	3.4 ^b ±2.16	4.5 ^a ±2.05
2 nd Upstream sample B	3.6 ^c ±2.16	3.7 ^b ±1.69	4.6 ^a ±2.16
1 st Downstream sample C	3.7 ^c ±2.45	4.6 ^b ±1.25	5.3 ^a ±2.16
2 nd Downstream sample D	3.7 ^c ±1.69	4.4 ^b ±1.25	5.3 ^a ±2.05

*Bacterial counts are expressed as counts (x10⁶ cfu/g). Data are expressed as mean ± standard deviation of triplicate trials. Values with different superscripts (a,b,c) across each row are significant (P<0.05).

For Ikot Effanga Mkpa stream, downstream sample A had the highest bacterial counts of 6.7±0.94x10⁶ cfu/ml for January, 9.7±1.69x10⁶cfu/ml for February and 17.4±2.05x10⁶ cfu/ml for March samples (P<0.05), while upstream sample D had the lowest bacterial counts of 4.4±2.05x10⁶ cfu/ml for January, 5.9±0.47x10⁶ cfu/ml for February and 15.1±1.25x10⁶ cfu/ml for March (P<0.05).

However, Ikot Effanga Mkpa river downstream sample C had the highest bacterial counts of 9.4±1.69x10⁶cfu/ml for January, 6.7±1.69x10⁶cfu/ml for February and 9.5±0.82x10⁶cfu/ml for March, while upstream sample D had the lowest counts of 4.7+2.16x10cfu/ml for January, 5.4+3.68x10cfu/ml for February and 5.5±1.69x10⁶ cfu/ml for March (p<0.05).

Table 3 shows the mean total bacterial counts of Lemna dumpsite decomposing solid waste, leachate, Ikot Effanga Mkpá stream and river samples during the wet season of June-August, 2011. The results obtained showed that soil sample C had the highest bacterial counts of $8.3 \pm 1.69 \times 10^6$ cfu/g in August, $6.3 \pm 3.74 \times 10^6$ cfu/g in June and $6.3 \pm 2.4 \times 10^6$ cfu/ml in July ($P < 0.05$) while sample D had the lowest bacterial counts of $3.7 \pm 2.05 \times 10^6$ cfu/ml in June, $5.7 \pm 2.16 \times 10^6$ cfu/g in August and $6.3 \pm 1.24 \times 10^6$ cfu/ml in July ($p < 0.05$). For leachate samples, location B consistently had the highest bacterial counts of $6.2 \pm 2.05 \times 10^6$ cfu/ml in June, $6.4 \pm 3.29 \times 10^6$ cfu/ml for July and $7.2 \pm 2.05 \times 10^6$ cfu/ml for August ($P < 0.05$), while location D had the lowest counts of $4.0 \pm 1.41 \times 10^6$ cfu/ml in June, $4.2 \pm 2.62 \times 10^6$ cfu/ml in July and $4.6 \pm 2.45 \times 10^6$ cfu/ml in August. However, location A for decomposing solid waste had the highest counts of $7.4 \pm 3.39 \times 10^6$ cfu/g in August, $7.2 \pm 1.29 \times 10^6$ cfu/g in July and $5.8 \pm 3.68 \times 10^6$ cfu/g in June ($P < 0.05$) while location D had lowest counts of $4.6 \pm 1.63 \times 10^6$ cfu/g in June, $3.1 \pm 1.73 \times 10^6$ cfu/g in June and $6.4 \pm 3.29 \times 10^6$ cfu/g in August ($P < 0.05$) respectively. For Ikot Effanga Mkpá stream samples, the first and second upstream samples were used as the control sample while the first and second downstream samples were used as the test samples analyzed.

The first downstream samples (sample C) had the highest bacterial counts of $7.5 \pm 2.05 \times 10^6$ cfu/ml in August, $6.6 \pm 2.45 \times 10^6$ cfu/ml in July and $4.6 \pm 1.63 \times 10^6$ cfu/ml in June ($P < 0.05$), while upstream sample A had the lowest bacterial counts of $3.6 \pm 1.25 \times 10^6$ cfu/ml in June, $4.3 \pm 2.10 \times 10^6$ cfu/ml in July and $6.3 \pm 2.16 \times 10^6$ cfu/ml in August ($P < 0.05$).

431 Above all, Ikot Effanga Mkpa river first downstream sample C had the highest
432 bacterial counts of $5.3 \pm 2.16 \times 10^6$ cfu/ml in August, $4.6 \pm 1.25 \times 10^6$ cfu/ml in July and
433 $3.7 \pm 2.45 \times 10^6$ cfu/ml in June counts ($P < 0.05$), while first upstream samples had the
434 lowest counts of $3.2 \pm 1.63 \times 10^6$ cfu/ml in June, $3.4 \pm 2.16 \times 10^6$

435 DISCUSSION

436 The Lemna solid waste dumpsite is an unlined, uncontrolled, unplanned
437 and open dump located by Parliamentary Extension Road in Calabar metropolis.
438 This dumpsite is used by Calabar Municipal Council for waste disposal and so
439 holds a lot of household wastes that are received on daily basis. The level of
440 pollution, seepage into the underground water, contamination of the nearby
441 stream/river and the potential impacts on public health in relation to solid waste
442 management at the dumpsite was effectively studied by sampling soil at the
443 dumpsite, leachate, air, nearby stream and river water during the dry and wet
444 seasons.

445 The study revealed that the composition, storage and disposal of solid
446 waste in Calabar metropolis potentially have environmental and public health
447 implications. Health risk assessment of solid waste management in the
448 metropolis shows that, only about 70% households have appropriate containers
449 as dustbins. Moreover, central depots where each household can deposit wastes
450 for collection by garbage trucks and tippers are not evenly located along most
451 streets and, in most cases, located very far away from most available space (Eja
452 *et al.*, 2003). This situation is not different in most Nigerian cities including

453 Abuja till date, as reported by Aliyu (2010). Solid wastes are not sorted out
454 (separated) into biodegradable and non-biodegradable wastes as is the practice
455 in developed countries. In view of this, bottles and tins are also separated at the
456 point of collection in order to facilitate proper handling by authorities (Eja *et*
457 *al.*, 2000) while some of the separated wastes could be recycled. Industrial
458 waste which normally contains toxic chemicals and sometimes radio-active
459 substances including electronic wastes, are dumped together with domestic,
460 market and commercial wastes which poses very serious health consequences.

461 It was observed in this study that wastes conveyed in trucks and tippers to
462 disposal sites were covered with tarpaulin which has helped partly to reduce
463 aerial spread of particulate substances and odour. But because the disposal site
464 is an open dump, aerial pollution seems to be very high as wastes are being
465 discharged from trucks/tippers at distances within a few meters from the
466 dumpsite. This implies that residents living near the dumpsite are at risk of
467 contracting air borne infections from bacteria, fungi or toxic chemical
468 substances. This is quite possible during the dry windy period of the year
469 (January to March) which was when this study was carried out, with mean
470 bacterial counts ranging from 36.5 ± 0.06 to 45.2 ± 0.08 within 10 meters from the
471 dumpsite of study. Fungal counts also ranged from 14.0 ± 1.25 to 18.0 ± 2.87
472 within 10 meters from the dumpsite. However, the further away from the
473 dumpsite, the lesser the level of aerial contamination by particulate substances.

474 These findings indicate that the air environment around the waste
475 dumpsite is usually contaminated by particulate substances. Although the
476 physicochemical parameters in air were not measured, dust, oxides of nitrogen,
477 sulfur dioxide, carbon monoxide, hydrocarbons, radioactive substances and a
478 trace of toxic elements have been reported to be associated with air pollution
479 caused by solid waste incineration (Zach *et al.*, 2000).

480 The bacterial and fungal counts from decomposing solid waste, soil at
481 dumpsite, leachate, Ikot-Effanga Mkpa stream and river water samples were
482 generally high during the three months of sampling from January to March,
483 2011 (Table 2 and table 3). Both bacterial and fungal counts showed highly
484 significant difference ($P < 0.05$) between the sources of samples, months of
485 sampling and locations of sampling. Least significant difference (LSD) test at
486 5% level of probability showed that decomposing solid waste had the highest
487 fungal counts followed by soil at dumpsite, leachate, Ikot-Effanga Mkpa stream
488 and Ikot-Effanga Mkpa river in that order. Similarly, fungal growth was highest
489 in March, followed by February and then January in that order. This indicates
490 that there will be high risk of contracting fungal infection from solid wastes
491 dumps during the month of March, probably as a result of dampness arising
492 from slight rain showers during this month.

493 The potential for disease epidemics from the open dumping of solid waste
494 in Calabar metropolis is high. Most of the bacterial and fungal isolates from the
495 solid waste, soil at dumpsite, leachate, Ikot Effanga Mkpa stream and river

appears to be pathogenic. Of the thirteen bacterial isolates isolated from the waste samples, five were coliform bacteria (*Escherichia coli*, *Klebsiella*, *Shigella*, *Enterobacter* and *Serratia*). The percentage occurrence of *Shigella* and *Enterobacter* did not differ significantly ($P>0.05$) unlike that of *Escherichia coli* and *Klebsiella* that showed a high significant difference ($P<0.05$) in soil at dumpsite. *Salmonella* and *Serratia* had same percentage of occurrence. The presence of coliforms such as *Escherichia coli*, *Klebsiella* etc. clearly indicates that the Ikot Effanga Mkpwa waste dumpsite is contaminated with faecal matter. All the bacterial isolates recovered from the waste dumpsite samples except *Chromobacterium violaceum*, *Proteus*, *Micrococcus luteus* and *Serratia* sp, are directly implicated in food-borne infections such as diarrhea, typhoid, and gastroenteritis. Human faecal matter presence in virtually all the points/locations of sampling in Calabar metropolis dumpsite and as such presents potential health problems not only to waste workers, but also to scavengers, other users of the same municipal drop-off point, and even small children who like to play in or around waste containers. The usual disease pathway include placing contaminated hands in the mouth or eating food, through vector insects such as cockroaches or mosquitoes, or directly inhaling airborne dust particles contaminated with pollutants.

It is pertinent to note here that, the presence of *Escherichia coli* 55 (13.31%), 48 (8.33%), *Staphylococcus aureus* 44 (10.65%) and *Micrococcus luteus* 53 (12.83%) in the soil and solid waste indicates a serious health risk

518 associated with soil and decomposing solid waste. *Micrococcus luteus* on
 519 human skin transforms compounds in sweat into compounds with an unpleasant
 520 odour (Greenblat *et al.*, 2004). Other pathogens show high frequencies in
 521 leachate and Ikot Effanga Mkpá river and particularly Ikot Effanga Mkpá
 522 stream which is a source of water supply downstream. PAI (1982) reported that
 523 as long as solid waste disposal is essentially of the simple dumping type, its
 524 effects on land pollution need to be stressed strongly. Some of the most
 525 common contaminants contributing to land pollution around urban centers are
 526 household refuse especially food remnants, packing materials such as papers,
 527 cartons, boxes, plastics, tyre residuals, cans and ash resulting from burning; also
 528 organic industrial residuals such as those from cannery operations like pulp, pits
 529 and culls, etc (Eja *et al.*, 2010) often contribute immensely to urban land
 530 pollution.

531 From the environmental point of view, the pollution from open dumping of
 532 waste could result in the production of not only unsightliness but also in the
 533 production of bad odours resulting from the decomposition of solid wastes.
 534 From public health point of view, such improper waste disposal techniques can
 535 become a serious health hazard through creating a suitable environment from
 536 which diseases can be transmitted. A report by PAI Associate International
 537 opines that such communicable diseases may be fly borne. They include
 538 typhoid, dysentery, cholera, onchocerciasis, sandfly fever and conjunctivitis,
 539 others may be rodent-borne zoonosis, e.g. echinostomiasis, haemorrhagic

540 septicaemia, while some may be mosquito-borne diseases such as filariasis,
541 dengue, malaria and yellow fever. Bassey and Andy, 2015 advocated the use
542 aqueous of Editan (*Lasianthera africana*), Ikongetidot (*Veronia amygdalina*) and
543 Atama (*Heinsiacrinata*) that have demonstrated effective spectrum of activity
544 against most isolated pathogenic bacteria an alternative regimen. Soilborne
545 fungal diseases associated with infected buried waste may also be related to
546 open dumping system of waste disposal (PAI, 1982; Bassey *et al.*, 2015).

547

548 **Conclusion**

549 From that tremendous useful information obtained in this comprehensive study,
550 it is pertinent to conclude that the open waste dump at the Ikot-effanga mkpa
551 dumpsite constitute a source of microbial and toxic chemical contamination of
552 the dumpsite, the underground water, Ikot effanga mkpa stream and river
553 through run-off inputs. This poses serious health risk and destruction of
554 biodiversity in both terrestrial and aquatic ecosystems of the area. The situation
555 could be aggravated by the poor storage systems in homes and establishments
556 thus constituting good channels for disease transmission by flies, mosquitoes
557 and rats. Further assessments could be need during the rainy season to have a
558 comparative idea of the level
559 effanga mkpa solid waste dumpsite is of great public health concern as it
560 contains microbial pathogens capable of initiating various infectious diseases in

Calabar metropolis. The dumpsite has to a greater extend influenced the pollution of the air, the soil, and surface water bodies within the vicinity.

REFERENCES

Aliyu, B. N. (2010). Analysis of municipal solid waste in Kano metropolis, Nigeria. *Journal of Human Ecology*, 31(2), 11-119.

Anijah-Obi, F. N. (2001). *Fundamentals of environmental education and management*. Ibadan: Spectrum books, 23-32.

Atlas, R. M. & Bartha, R. (1992). Degradation and mineralization of petroleum by two bacteria isolates from coastal waters. *Biotechnology and Bioengineering*, 14, 296 -308.

Asikong, B. E. & Udofia, U. U. (2005). *Introduction to environmental microbiology, pollution and waste management*. Calabar: MABASS Printers, 105 – 182.

American Public Health Association (APHA) (1998). *Standards methods for the examination of water and waste water* (20th ed.). Washington DC.: American Public Health Association, 1220.

Atlas, R. M. & Bartha, R. (1992). Degradation and mineralization of petroleum by two bacteria isolates from coastal waters. *Biotechnology and Bioengineering*, 14, 296 -308.

Bassey, I. U. & Andy, I. E. (2015). Antibacterial (spectrum) activity of some medicinal plants against extended spectrum beta-lactamase producing Escherichia coli, Klebsiella pneumonia and Proteus mirabilis. *Der Pharmacia Lettre*, 7 (2):260-263

Bassey, I. U., Andy, I. E., Asikong, B. E. & Brooks, A. A. (2015). Potentials of organic fertilizer application as biocontrol for some soil borne fungal pathogens in ogoja–nigeria. *Journal of Biopesticides and Environment*, 1, 58-62.

B. E. Asikong, O. U. Udensi, J. Epoke, E. M. Eja & E. E. Antai (2013). Microbial Analysis and Biogas Yield of Water Hyacinth, Cow Dung and

- 595 Poultry Dropping Fed Anaerobic Digesters. *British Journal of Applied*
596 *Science & Technology*, 4(4): 42231-0843
- 597 Eja, M. E. (2000). Environmental impact assessment (EIA): Problems and
598 application in Nigeria in the millennium. *International Journal of*
599 *Tropical Environment*, 217 – 228.
- 600
- 601
- 602 Eja, M. E., Alobi, N. O., Ikpeme, E. M., Ogri, O. R. & Inyang, A. O. (2010).
603 Environmental and public health-related assessment of solid waste
604 management in Uyo, Akwa Ibom State, Nigeria. *World Journal of*
605 *Applied Science and Technology*, 2 (1), 110 – 123.
- 606 Ekpo, B. O., Ibok, U. J. & Umoh, N. D. (2000). Geochemical evaluation of
607 suitability of sites for hazardous waste disposal: A case study of recent
608 and old waste disposal sites in Calabar Municipality, SE Nigeria.
609 *Environmental Geology*, 39, 121.
- 610 Etok, C. A., Udo, S. M. & Eja, M. E. (2004). *General microbiology practical*
611 *manual*. Calabar: Albison Printing Press, 12-43.
- 612
- 613 Eno, J. U., Trenchard O. I., Joseph A. O., Anthony O. A. & Ivara E. E. (2009).
614 *Manual of soil, plant and water analyses*. Lagos: Sibon Books, 1 - 102.
- 615 Feacham, R. G., Bradley, D. J., Garelick, H. & Mara, D. D. (1983). *Sanitation*
616 *and diseases – health aspects of excreta and wastes water management*.
617 New York: John Wiley, 385.
- 618 Gee, G. W. & Bauder, J .W. (1986). Particle size analysis. In A. Klute (Ed.), *Methods*
619 *of soil analysis, part 1*. New York: McGraw Hill, 383-411.
- 620 Greenblat, C. L., Baum, J., Klein, B. Y., Nachshon, S., Koltunov, V., Cono, R.
621 J., (2004). *Micrococcus luteus* survival in amber. *Microbial Ecology*, 48
622 (1), 120-127.
- 623
- 624 Holt, J. G. Krieg, N. R. Sneath, P. H. A. & Williams, S. T. (1994). *Bergey's*
625 *manual of determinative bacteriology* (9th ed.). New York: Lippincott
626 Williams & Wilkins, 1-787.

- 627 Khupe, J. S. N. (1996). Water supply, sewage and waste management for
628 Gaborone, Botswana. *Ambio*, 25, 134-137.
- 629 Monica, Cheesbrough (2005). *District laboratory practice in tropical countries*,
630 *part 2*. Biochemical tests to identify bacteria. 62-70.
- 631
632 PAI Associate International (1982). *A report on urban solid wastes*
633 *management in fifteen (15) Nigerian cities*. Lagos: PAI Associate
634 International, 11 – 18.
- 635 Rorrer, G. (1999). Heavy-metal ions, removal from wastewater. In The Wiley (Ed.),
636 *Encyclopaedia of environmental pollution and cleanup*. New York: John Wiley
637 and Sons, 991 – 779
- 638 World Health Organization (WHO) (2007). *Guidelines for drinking water*
639 *quality, health criteria and other supporting information*. Geneva: World
640 Health Organization, 121-133.
- 641 Yaliang, Y., (1996). Changzhou, China: Water supply, sewage treatment and
642 waste disposal strategies for sustainable development. *Ambio*, 25 (2), 86 –
643 89.
- 644 Zach, A., Binner, E. & Muna, L. (2000). Improvement of municipal solid waste
645 quality for landfilling by mechanical biological pre-treatment. *Waste*
646 *Managment and Research*, 18, 25 – 32.