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Microbial and Physico-Chemical Assessment of Soil and Water Around Waste Dump Sites in Lagos

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Abstract

In Nigeria, the reliance on sanitary landfills is a common phenomenon in the disposal of waste materials. The aim of the study was to ascertain the physicochemical and microbiological effect landfill has on its surrounding soil and water. Four water samples and five soil samples were collected each from Ile-Epo and Legacy dumpsites and the adjoining areas. Physicochemical parameters determined were temperature, pH, total dissolved solids (TDS), total hardness (TH), and electrical conductivity. Most of these parameters indicated pollution but were below the World Health Organization (WHO) limits for consumption in the water. Microbiological analysis was carried out using standard microbiological procedures. The mean bacteria count and fungal count for water and soil samples are 26.41 CFU/mL and 10.00 CFU/mL; and 26.30 and 14.50 (CFU/G) respectively. The antibiotic susceptibility pattern of the bacterial isolates against conventional antibiotics displayed varying degree of susceptibility and resistance; the bacterial contaminants were susceptible to Augmentin, Gentamycin and Chloramphenicol and resistant to Pefloxacin, Amoxacilin, Tarivid, Streptomycin, Sparfloxacin and Ciprofloxacin. The results obtained in this study showed that the leachate generated from the landfill site has a minimal impact on the groundwater and soil quality in the locality.

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Introduction

Increase in the amount of wastes can be attributed to the massive expansion of the population in the towns and cities due to many people moving from the rural areas to the cities (Ali *et al*., 2016). Waste is an unwanted or unusable material, substances or by-products eliminated or discarded as no longer useful or required after the completion of a process. The wastes generated are from residential, commercial, industrial, institutional, construction, demolition, agricultural and municipal services (Salam, 2010). Some of the wastes in the waste dump sites include; broken glass, raw steel metal, food residue, human waste, wood, plastic, textile, nylon, and so on, that poses threat to human health. The waste dumps serve as breeding ground for rodents, mosquitoes, flies and certain microorganisms which can cause diseases (Ayilara *et al*., 2020).

In most developing countries, open dumping has been the only management option for solid waste disposal. Ecological impacts such as land degradation, water and air pollution are related to improper management of solid wastes (Khajuria *et al*., 2008). The occurrence of these dump sites deteriorates the soil quality and decreases vegetation abundance. Soils

at disposal sites show high pH, total dissolved solids and heavy metal concentrations, i.e., Lead (Pb), Copper (Cu), Nickel (Ni), Zinc (Zn). The major sources of heavy metals in landfills are the co-disposed industrial wastes, incinerator ashes, mine wastes and household hazardous substances such as batteries, paints, dyes, inks, etc. (Alam and Ahmade 2013). This causes adverse effects on human health, animals and the soil's fertility and quality.

Therefore, solid wastes affect the physicochemical properties of the soil which contributes to poor vegetation (Adetutu *et al*., 2012). Absorption of the content of the polluted soil through the root system retards plant growth and hinders the normal metabolism of the plant (Salam, 2010). The presence of this waste on the soil also aids in the colonization by fungi and bacteria carrying out the degradation and transformation of biodegradable materials in the waste (Ayilara *et al*., 2020). Their metabolic activity of detoxifying materials from complex organic molecules into simpler less toxic molecules is attributed to their high growth rate, metabolism and collective ability to degrade a wide variety of naturally occurring organic materials (Adetutu *et al*., 2012).

Dumped solid wastes produce leachate; a liquid that drains or leaches from a landfill as a result of water present in the landfill or rainfall, which contains variety of chemicals like detergents, inorganic chemicals, complex organic chemicals and metals (Arukwe *et al*., 2012). During infiltration of water by rainfall, leachate leaves the dumping ground laterally or vertically and finds its way into the ground water or nearby surface water thereby causing contamination. Dumped solid wastes release its initial interstitial water gradually and some of its decomposition by-products get into the water moving through the waste deposit (Sulam, 2010).

Leachates percolating into the groundwater is a mixture of highly complex contaminants such as potentially toxic metals (e.g. lead, mercury, cadmium, chromium etc.); persistent organic pollutants (POPs) (e.g. dioxins, furans, polycyclic aromatic hydrocarbons (PAHs), polybrominated diphenyl ethers (PBDEs) etc); inorganic compounds (e.g., ammonium, sulphates, chlorides) as well as bacterial contamination – total coliform and faecal coliform (Guerrero *et al*., 2013; Kanmani & Gandhimathi, 2013 and Oyeku and Eludoyin, 2010). Many communities in Lagos, Nigeria depend on groundwater supply for domestic purposes. These dumpsites poses a major threat to groundwater resources receiving a mixture of municipal, commercial and mixed industrial wastes (Adewole, 2009). The presence and potential exposures of the community to groundwater contaminants may contribute to the deterioration of human health, from simple poisoning to cancer, heart diseases and tetratogenic abnormalities (Su, 2008).

Some of the wastes in the dump will rot and, in the process, it will smell or generate methane gas which contributes to greenhouse effect and pollute the air. Incinerating the wastes also is not advisable because plastics tend to release toxic substances, such as dioxins, when they are burnt. This would pollute the air and contribute to acid rain. The short-term effect of the air pollution due to presence of waste dumps includes; congenital anomalies, asthma and respiratory infection (Alam & Ahmade, 2013). Spore producing microbes around the dump sites can release their spores that will be inhaled by those living around the dumps or those waste picking within the open dump sites and this can pose serious health risk (Salam, 2010).

In Lagos Nigeria, there is paucity of information on the types of microorganisms associated with communities situated close to dump sites. There is therefore need to isolate, characterize and identify the types of bacteria and fungi associated with areas situated close to waste dump sites. As wastes disposed in the dumps alter the properties of

the soil, air and water which affects the plants, animals and humans around it. Organic waste may also act as an important breeding site for disease causing vermin including flies, insects and rodents, which are vectors of diseases such as cholera, diarrhea, dysentery and typhoid fever (Fobil *et al*., 2008). This study aims to investigate the microbial and physicochemical characteristics of soil and water around waste dumpsite and how it affects human health.

Materials and Methods

Sample Area

Samples were collected from two waste dump sites, Ile-Epo Landfill and Legacy Waste dump. Ile-Epo Landfill, a 3.0 hectares land of 6o36'29"N Latitude and 3o17'35"E Longitude is located at Ile Epo Busstop along Abule Egba - Agbado road, Lagos State. It is a large landfill that consists of various kinds of wastes. Scavengers are found in this landfill, people live in this landfill and a market where various food items are sold lies side by side with this landfill. This creates a huge concern on the health risks associated with the close proximity of people and food items to this landfill.

Legacy Waste dump is located at Legacy Road, Ipaja, Ayobo, Lagos State. It is not as large as the Ile Epo landfill and consists majorly of municipal wastes from homes, shops, etc. It has geographical coordinates of 6° 36' 0" North, 3° 14' 0" East.

Sample Collection

Water and soil samples were collected from both landfills. Five soil samples were collected, the surface debris was removed and subsurface soil dug to a depth of 5 cm into sterile duplicate sampling bottles and labelled. Four water samples were collected from taps from houses around the dump site in sterile bottles for analysis. Samples were transported to and analysed in the laboratory, soil samples were spread in petri dishes and air dried, the dried soil was grinded and passed through an aluminium sieve with 2mm wire mesh. The sample was stored prior to analysis.

Physicochemical Analysis

pH : HANNA pocket sized pH meter (HI77700P) (HANNA Instruments, USA) was used to analyze the pH. The pH electrode of the meter was first calibrated with standard buffer solutions with known pH values. Soil was diluted in distilled water and stirred. The electrode was rinsed using distilled water, dried off with clean tissue, placed in the sample solution and the value was recorded. To check pH of water sample, the meter is calibrated using standard buffer, rinsed with distilled water and dried off. The water sample was measured and the electrode inserted for reading and the value was recorded (Arukwe *et al*., 2012).

Total dissolved solids (TDS)/ Electrical conductivity (EC)/ Temperature: The total dissolved solids, electrical conductivity and temperature of the water sample was measured using the Bench top conductivity meter (Bante510) (Bante Instruments, China) and result was recorded.

Hardness of Water: 50 ml of EDTA (Ethylenediaminetetraacetic acid) was prepared into a burette, 10 ml of the test water is pipetted into a conical flask and 5 ml of ammonia-based pH 10 buffer is added to it. 2 drops of indicator Eriochromschwartz-T was added and the color turned red. EDTA was transferred through the burette into the flask until it turns sky blue. The end point was recorded and the titration was repeated (Anthony, 2012).

Total Solids: A clean evaporating dish was used and weighed as weight 1. The sample was poured into the dish and content evaporated using a steam bath. The dish was then placed in the oven at 120oC for 1 hour. The dish was allowed to cool and weighed as weight 2. The two weights were subtracted and result recorded (VenkataRamaiah & Krishnaiah, 2014).

Microbiological Analysis

Cultivation and enumeration of Bacteria and Fungi

Each sample of 1 g freshly air-dried fine soil thoroughly shaken in 9 ml distilled water. An aliquot (1.0 ml) was transferred into the next test tube and diluted serially in one-tenth stepwise to 10-10 dilution. From the dilutions of each soil sample, 1 ml was transferred into the petri dish and media; Potato Dextrose Agar (PDA) (Himedia laboratories, Vadhani, India), Nutrient Agar (NEOGEN Heywood, United Kingdom), Eosin Methylene Blue (Himedia laboratories, Vadhani, India), and MacConkey Agar (Axiom Medical Limited, United Kingdom)) using pour plate method. 10 ml of Streptomycin was added to 1000 ml of PDA media, to prevent the growth of bacteria. The poured plate was gently swirled and the agar left to gel. All inoculated plates were inverted and incubated at 37oC for 24 hours except PDA plates that was inoculated at 28oC for 3-7 days. Plates were examined for growth and colonies were counted and recorded (Cheesbrough, 2006).

For the water sample, 1ml of each water sample was diluted in 9 ml distilled water. An aliquot (1.0 ml) was transferred into the next test tube and diluted serially in one-tenth stepwise to 10-10 dilution. 1 ml of aliquot is transferred using pour plate method and inoculated using the same media and at the same temperature as was used for soil samples. The preparation of media and cultivation of bacteria and fungi was carried out aseptically. All isolates were characterized and identified according to standard microbiological procedures (Cheesbrough, 2006).

Characterization and Identification of Fungi Isolates

Pure cultures of fungi were obtained by sub culturing discrete colonies onto freshly prepared potato dextrose agar plates and inoculated at room temperature (28± 2oC). Lactophenol cotton blue stain was used in the identification of fungi isolate. A drop of lactophenol solution was placed onto a clean slide. The wire loop was sterilised using Bunsen burner with blue fame. Using the wire loop a small amount of the fungal culture was removed from the edge (younger colonies). The fungal culture was spread gently on the slide using the wire loop in order to tease out the fungal structures, the coverslip was gently placed on the slide for examination under the microscope. The fungal elemental characteristic was detected, examined and recorded. The identification of fungal isolates was done by comparing the result of their cultural and morphological characteristics with those of known taxa.

Antibiotics Susceptibility Testing

The antibiotics susceptibility test of the isolates was carried out using the Kirby-Bauer disk diffusion technique according to the methods recommended by Clinical Laboratory and Standards Institute (CLSI, 2018). Discrete colonies of the isolates were inoculated into 5ml of normal saline standardized with 0.5 McFarland standard suspensions. Sterile cotton wool swab was used for the inoculation of the bacterial suspension to freshly prepared Mueller-Hinton agar plates prepared according to manufacturer's instructions (CLSI, 2018). The antibiotic sensitivity discs were aseptically and spaciously placed (20mm

away from each other) on the inoculated Mueller-Hinton agar plates. The antibiotic discs used were: SXT; Septrin (30µg), R; Rocephin (25µg), AM; Amoxacillin (36µg); CN; Gentamycin (10µg), PEF; Pefloxacin (10µg), APX; Ampiclox (30µg), S; Streptomycin (30µg), E; Erythromycin (10µg) for Gram negative isolates. while SXT; Septrin (30µg), CH; Chloranphenicol (30µg), SP; Sparfloxacin (10µg), CPX; Ciprofloxacin (30µg), AM; Amoxacillin (30µg); AU; Augmentin (10µg), PEF; Pefloxacin (30µg), OFX; Tarivid (10µg) for Gram positive isolates. After incubation, the test plates were examined for confluent growth and zone of inhibition. The diameter of each zone of inhibition was measured in millimetre (mm) using a ruler on the underside of the plate. The interpretation of the measurement as sensitive, intermediate and resistant were made according to CLSI manual (CLSI, 2018).

Results

Table 1: The Physicochemical results obtained for soil and water samples

Location	Samples	pH	Electrical Conductivity	Temperature	Total Dissolved solids	Total Solids	Hardness of water
ILE-EPO	Water sample 1	6.1	456	28.5	228	310	93.6
	Water Sample 2	6.5	457	28.1	230	312	93.9
	Soil Sample 1	8.1	-	-	-	-	-
LEGACY	Water Sample 1	6.1	43.7	25.4	22.0	158	31.5
	Water Sample 2	6.8	12.7	25.8	64.7	123	25.6
	Soil Sample 1	7.9	-	-	-	240	-
	WHO Standard	6.5 - 8.5	1000µs/cm	<32°C	1000 mg/l	1000mg /l	NS

NS – Not specified

Effect of wastes on the Physico-chemical properties of water and soil

The effect of the waste on the physic-chemical parameter of water and soil in the locations of study was determined by comparing the values of physicochemical parameters obtained with the standard limit. The result is presented in Table 2.

Table 2: Comparison of values of physico-chemical properties obtained with standard limit

Sample		N	Mean	WHO limit
Water	Ph	4	6.38± 0.34	6.5- 8.5
	Electrical Conductivity	4	242.35±247.60	1000
	Temperature	4	26.95±1.58	< 32
	Total Dissolved	4	136.18±108.60	1000

	Solids			
	HARDNESS	4	61.15±37.72	150(NSDWQ)
	Total Solids	4	225.750±99.47	1000
	Dissolved Oxygen	4	4.61±1.73	7.5
Soil	pH	5	8.00±0.22	6.5 - 8.5
	%TOC	5	11.25±1.26	-

Table 2 shows that for the water around the waste dump site, mean pH value obtained is 6.38±034 which when compared to the WHO limit is of between 6.5 to 8.5 shows that the pH is slightly acidic. Other physicochemical parameters of the water around the waste dump site are the electrical conductivity (242.35±247.60), temperature (26.95±1.58), total dissolved Solid (136.18±108.60), hardness (61.15±37.72), total solids (225.750±99.47) and dissolved oxygen (4.61±1.73) were also less than the recommended values by WHO/NSDWQ (National Standards for Drinking Water Quality). For the soil sample, the mean pH is 8.00. The mean percentage of TOC (Total Organic carbon) found in the soil was 11.25%.

Table 3: Total viable count, Total coliform, Total faecal coliform and Total fungal count obtained.

Location	Samples	Dilution factor	Total Viable Count	Total Coliform	Total Fecal Coliform	Total Fungi count
	Water		**CFU/mL**			
	Soil		**CFU/G**			
ILE-EPO	Water sample 1	10^{-7}	290	200	106	25
	Water Sample 2	10^{-7}	300	295	200	11
	Soil Sample 1	10^{-8}	250	300	240	30
	Soil sample 2	10^{-8}	300	300	239	50
	Soil sample 3	10^{-7}	290	295	225	46
LEGACY	Water Sample 1	10^{-7}	290	290	250	12
	Water Sample 2	10^{-5}	300	298	225	20
	Soil Sample 1	10^{-6}	290	300	240	30
	Soil Sample 2	10^{-8}	300	300	250	28

Table 4: Mean Bacterial and Fungal Counts in water and soil samples around waste dump site

Sample	Mean Bacteria Count(10^8)	Mean Fungi count (10^8)
Water	26.41± 5.68 (CFU/ML)	10.00 ± 10.60 (CFU/ML)
Soil	26.30±7.79 (CFU/G)	14.50±13.61 (CFU/G)
Total	26.35±6.74	12.57±12.18

Table 5: Difference in the microbial population of water and soil sample

Organism	Sample	Mean($10^{8)}$	Mean diff($10^{8)}$	Confidence Interval	
				LB($10^{8)}$	UB($10^{8)}$
Bacteria	Water	26.41± 5.68	0.11	-6.87	7.09
	Soil	26.30±7.79			
Fungi	Water	10.00 ± 10.60	-4.50	-19.14	10.14
	Soil	14.50±13.61			

Table 5 shows that difference in the bacterial count for water (26.41± 5.68) and soil (26.30±7.79) is 0.11. The confidence interval shows that the lower bound for the bacterial count between the water and soil sample is -6.87, while the upper bound is 7.09. The mean difference values lies between a negative and a positive value, indicating that the difference in bacteria population of the water and soil samples around waste dump site is not significant (negligible).

For the fungal population in water and soil sample around the waste dump site, it also shows that the difference in fungal counts between water (10.00 ± 10.60) and soil (14.50±13.61) sample is 4.50. The confidence interval shows that the lower bound for the fungal count between the water and soil sample is -19.14, while the upper bound is 10.14, indicating the mean difference in fungi count between the water and soil sample found around the waste dump site is also not significant.

Table 6: Antibiotics susceptibility test

ANTIBIOTICS / ORGANISM	AU	CN	PEF	AM	OFX	S	SXT	CH	SP	CPX
Escherichia coli.	S	S	R	R	R	R	R	S	S	R
Klebsiella Pneumoniae	S	S	R	R	R	R	S	S	R	S
Salmonella enterica	S	S	R	S	R	R	R	S	S	R
Salmonella paratyphi A	S	S	R	S	R	R	R	S	R	R
Pseudomonas aeruginosa	S	S	R	R	R	R	S	S	R	S
Enterobacter aerogenes	S	S	R	R	R	R	S	S	S	R

Key: R – Resistant, S – Sensitive, AU –Augmentin, CN –Gentamycin, PEF-Pefloxacin, AM-Amoxacilin, OFX- Tarivid, S-Streptomycin, SXT- Septrin, CH- Chlorophenicol, SP- Sparfloxacin, CPX-Ciprofloxacin

Discussion

From the analysis carried out on the water samples around the waste dump sites, pH had mean value 6.04 – 6.72, slightly acidic and below WHO standard (6.5 – 8.5). A similar result was obtained by Anthony, (2012), the pH ranged from 4.63 – 7.43. The pH of water is very important because changes in pH values may affect the toxicity of microbial poisons in the water (Su, 2008). This slight acidity of the water examined in this study, poses health risk to consumers who use the water for cooking, washing, drinking, bathing and other domestic purposes. The pH value for soil sample was 8.00 which is within the limit set by WHO.

The values for electrical conductivity (EC) and total dissolved solids (TDS) were below the permissible limit by WHO standard, Arukwe *et al*., (2012) observed similar results. EC is a function of magnesium, calcium, sodium and sulphates in water, the conductivity level of the samples reveals that there are moderate dissolved salts in the water, and it is within limits approved for safe drinking water. TDS comprises of inorganic salts and small amounts of organic matter that are dissolved in water, it indicates presence of low impurities. Results obtained by Ali *et al*., (2016) agrees with the values obtained in this study. The temperature of the water analysed was within the range of 25.37-28.53oC, it corresponds with the temperature of water in the storage tanks 26.0 to 27.6oC, observed in all the sampling points that lie within the range of < 32oC for safe drinking water by VenkataRamaiah & Krishnaiah (2014). The temperature range observed in this work will discourage rate of chemical and biochemical reactions, solubility of gases in the water which could impact negatively on the taste and odour of the water at higher temperatures.

Based on the WHO standards, water samples are unacceptable for human consumption when it has high bacterial loads. According to US EPA standards, water samples in which coliforms are detected should be considered unacceptable for drinking as they are regarded as the principal indicators of water pollution. The organisms isolated in this study include; E.coli, P. aeruginosa, S. paratyphi A, S. enterica, Enterobacter aerogenes, Klebsiella pneumonia, Rhizopus stolonifera, Penicillium sp. and Aspergillus niger. The results in Table 2 revealed that all the water and soil samples from both areas had very high counts of total and faecal coliforms. Oyeku & Eludoyin, (2010) isolated Enterobacter, Pseudomonas, Escherichia, Salmonella from soil and water samples, this correlates from the results obtained in this work. The presence of faecal coliforms like E. coli and Klebsiella sp. indicated pollution by sewage. They are important human pathogens associated with a variety of infectious diseases such as gastroenteritis, typhoid fever, dysentery, urinary tract infection, etc.

The high count of these pathogenic bacteria in the water sources could be due to any of the following: improper disposal of sewage and wastewater from domestic activities, discharges from septic tanks and latrines close to some of the bore holes, in-appropriate siting of boreholes very close to dumpsites and extraction of ground water from very shallow aquifers. This is in agreement with the work of Kanmani and Gandhimathi (2006), which also stated that high bacterial load in borehole water supplies may be due to discharges from septic tanks and waste materials from a nearby dumpsite. Adetutu *et al*., (2012) and Su, (2008) in their articles also highlighted the presence of coliforms, faecal coliforms and pathogens (Escherichia coli, Streptococcus, Pseudomonas and Salmonella) in large numbers which was attributed to the emanation of these species from some sources such as seepages from septic tanks into household drinking water supply and soil, and unhealthier latrine systems. The presence of these indicator organisms in drinking water sources may provide an indication of water-borne problems which is a direct threat to

human health and is a matter of serious concern (Salam, 2010). Results of the water analyses reveals that most of the parameters analysed in the water samples from both areas were not within the acceptable water quality standards and therefore indicate the existence of pollution in these drinking water sources from both study areas. Continuous water quality monitoring in and around both dumpsite areas is encouraged.

Most of the bacteria displayed varying degree of resistance to multiple drugs. Escherichia coli were found to be susceptible to Chloramphenicol, Augmentin, gentamicin and Sparfloxacin, but displayed resistance to the other antibiotics tested (Pefloxacin, Amoxacilin, Tarivid, Streptomycin, Septrin, Ciprofloxacin). Pseudomonas aeruginosa was susceptible to Augmentin, Chloramphenicol, Gentamicin, Septrin and Ciprofloxacin but was also resistant to the other antibiotics screened (Pefloxacin, Amoxacilin, Tarivid, Streptomycin, Sparfloxacin, Ciprofloxacin). Similarly, Salmonella spp. exhibited susceptibility to Chloramphenicol, Augmentin and Gentamycin and Amoxicillin and resistance to others.

Conclusions

The results obtained in this study showed that the leachate generated from the landfill site has a minimal impact on the groundwater quality in the locality. The mean pH was observed to be lower than the WHO standard, which indicates that it to be slightly acidic; hence it needs to be treated for it to be potable. Faecal coliforms and fungal population was observed both in the soil and water samples. This indicates that the water and soil are contaminated and the water is unreliable for drinking water supply purposes and therefore puts emphasis on the need to improve on waste management practices and construct properly engineered sanitary landfill sites to curtail the pollution of groundwater and it also encourages the proper treatment of water before usage. Landfills should be sited faraway from residential areas. This would help in limiting the impact on health of humans. Sanitary and well-engineered landfills should be constructed, this would help in reducing the impact and influence that it has on soil, groundwater and humans. Wastes should be sorted out properly, reused and recycled. If sanitary landfill is properly designed and maintained, it will have less negative impact to man and the environment.

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