Research Article

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Journal of Toxicological Analysis

2018
Vol.1 No.1:6

Heavy Metal and Microbial Load Properties of Dumpsite Leachate: Case Study of Onitsha Dumpsite, South-East, Nigeria

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Rec date: April 12, 2018; **Acc date:** May 09, 2018; **Pub date:** May 11, 2018

Citation: Michaela EI, Odohb AO, Chukwurac EI, Bend MG. Heavy Metal and Microbial Load Properties of Dumpsite Leachate: Case Study of Onitsha Dumpsite, South-East, Nigeria. J Toxicol Anal. 2018, Vol.1 No.1: 6.

Abstract

Management of municipal waste has been an ambitious factor to sustainable development. In Nigeria most wastes are released into the surrounding with inconsiderable or no treatment. Microbial activities undertake degeneration of these wastes hazard and discharge as leachates. The study examined the heavy metals and microbial population characteristics of leachate from solid waste dumpsites aligning water body of the River Niger, Nigeria. Standard procedures were employed for the analysis. A comparison between metal permissible limits approved by FEPA, DPR, WHO and leachate sample as well as groundwater and soil samples obtained 45.6 km away from Onitsha dumpsite to ascertain significant differences in the result. Microbial population results were expressed in cfu/ml as: Total heterotrophic bacteria, total fungi, ranged from 6.23-9.79 Log cfu/ml, 5.25-6.64 Log cfu/ml respectively, Metals with high significant value with mean triplicate ± standard deviation such as Cd, Pb and Ni ranged from 0.536 ± 0.001, 0.655 ± 0.001 and 0.655 ± 0.001 respectively. This study indicated high significant level of Cd, Pb and Ni concentration as compared to the permissible limit. The study result indicated that leachate of the area possessed obnoxiously odoured, undesirably colored, highly turbid, alkaline, high microbial load, non-putrescible and putrescible organic substances that could have deleterious effect on groundwater quality. The study recommends effective treatment of effluent before discharged into the environment.

Keywords: Metals; Leachate; Dumpsite; Water; Effluent

Introduction

Leachate is a discharge interface from leaching, as of dissolvable organic constituents from pollute, landfill, etc., by sloping downward exude dregs water. The existence of leachate in town dilute has been traced to a synthetic waste junk with disadvantageous consequence on groundwater quality [1].

Dumpsite leachate comprise of organic substance (biodegradable and non-biodegradable), mineral pollutants and dangerous substances [2,3]. Hazardous substances in MSW are in the form of chemicals, heavy metals enclose worthless, batteries, pharmaceuticals, damaged automobile parts and many other diffuse products [4].

The emergence of leachate is as a result of combined biological and chemical reaction solid waste deposited in the landfill and if not controlled can be a major problem of contamination. Organic and inorganic compounds percolate out of the solid substances into a liquid phase resulting to wastewater with high contamination index that exceeds industrial and municipal effluent [5]. Leachate from landfill can serve as a major causative agent of health and environmental due to toxicity, groundwater, soil and surface water [6,7] which is an indicator for treatment of leachate before disposal. Many countries around the globe strictly enforce proper regulations regarding discharge of leachate [8].

One of the major sources of soil pollution emanates from the indiscriminate disposal of heavy metals. The causative agent of heavy metal pollution in the soil is through the disposal of metals such as Cu, Ni, Cd, Zn, Cr and Pb [9]. Although certain heavy metals (like Fe, Zn, Ca and Mg) have been reported to be of biological-importance to mankind and their daily medicinal and dietary values as recommended. Most importantly, the biological-importance of As, Cd, Pb, and methylated forms of Hg in human biochemistry and physiology have been reported to have no known effect at consumption even when in very low concentrations whether it can be toxic [10].

Heavy metals exert adverse and highly toxic effects on soil microorganism, thereby resulting in the alteration of the diversity, population size and activity of the soil microbial communities entirely [11]. The high concentration of Pb in soils may adversely alter soil productivity as well as very low

Pb concentration may eventually inhibit some vital plant processes such as photosynthesis, mitosis and ability to absorb water with toxic signs of dark green leaves, cause old leaves to be flaccid [12]. The uptake of metal by plant from soils at high concentrations accompanies a great health risk due to food-chain implications [13].

Onitsha as the area of studies is a city with various anthropologic activities ranging from mechanic workshops, market places, industries, banks, kiosk with disharmony that generates poor refuge disposal, stagnant dirty pools and ponds as well as poorly constructed and blocked drainages. The contamination index is dependent on the geographical region and category of waste deposited [14].

At the instance of these, the research work emphasis is on the characterization of dumpsite leachate, identifying the level of soil nutritional elements and their detrimental effect on both microorganisms that are of agricultural importance, plants for human consumption as well as the enhancement of crop production and nutritional values.

Materials and Methods

The study area

The study region is Onitsha, a town in Anambra state, southward eastward Nigeria. It is situated around within latitudes 6° 05' 39”N to 6° 12' 13”N of the equator and longitude 6° 45' 29”E to 6° 50' 07”E of the Greenwich Meridian. The study region (Onitsha Urban Area) overspread approximately 6366.851 sq km. It is located on the eastward bank of the river Niger and intercept areas such as; American lodge, Main market, GRA phase 1 and 2, Odeakpu, Fegge, Woliwo, Harbour business layout, Awada layout and Okpoko.

Sample collection

Samples were collected randomly at recognized and selected locations from the dumpsite. Duplicate samples at each sampling station were collected in May 2015 into well labelled sterile containers. The rainy weather samples were taken when precipitation had occurred. Collection of soil samples was done using a sterile sample collection bottle and transported to the laboratory using an ice box containing frozen ice packs.

Physicochemical properties

Due to indiscriminate disposal of scrapped metal, certain important parameters of the leachate in Onitsha were necessary to measure its characteristics. The parameters analyzed include physical features like color, temperature, turbidity, total dissolved solids, conductivity, cation exchange capacity, chemical/mineral constituents standard such as Cadmium, Silver, Aluminum, Molybdenum, Arsenic, Mercury, Manganese, Zinc, Copper, Nickel, Chromium, Magnesium, Iron, Lead and Cobalt. Organic contents such as total heterotrophic fungal/bacterial feature were investigated.

Analysis of the leachate

Analysis of leachate sample was carried out using the water and wastewater examination method [15]. pH was measured by Electrometric Method using Laboratory pH meter Hanna model H1991300 [16]. Determination of electronic conductivity was carried out according to APHA 2510 B guideline Model DDS-307 and Total dissolved solid was determined using APHA 2510 ATDS139 tester. Temperature of each sample was determined immediately after collection using a mercury thermometer. The analysis of leachate samples is in conformity with the [4] standard. Leachate sample was analyzed for its physicochemical and microbial characteristics.

Analysis of Physical Parameters

The analysis of physical parameters was the appearance, colour, odour, temperature, turbidity, conductivity and total dissolved solids. These were all measured in conformity with standard methods.

Analysis of inorganic constituents

The analysis of inorganic constituent was obtained with both colorimetric and titrimetric methods. The reagent and water samples were mixed until the solid dissolved. The solution was then dispensed into either comparator or checker disc as specified by the manufacturer. The addition of reagents to water sample until the color changed at the end points was the titration method employed.

Determination of metals

The flame atomic absorption spectrophotometry technique in accordance with the method described by Welz [17] to determine metals. The analysis of the following metals: Cobalt, Silver, Aluminum, Molybdenum, Arsenic, Mercury, Manganese, Zinc, Copper, Nickel, Chromium, Magnesium, Iron, Lead and Cadmium atomic absorption by spectrophotometer (AAS). Leachate samples were digested by add 50 mL of well-mixed sample, transferred to a beaker and heated, not attain boiling point, with the aid of a hotplate to ensure volume reduction to 15-20 mL. Repeat heating sample for 30 minutes with concentrated nitric acid (15 mL). The solution was allowed to cool to room temperature and carefully filter insoluble materials. The digested sample was preserved by transferred with deionized water to a 100 mL volumetric flask and diluted to volume quantitatively. Dilution and analysis of samples were done in duplicates.

Microbial enumeration

The microbial populations of total heterotrophic bacteria (THB), total fungi of the leachates were enumerated using serial dilution pour plate method of Pepper and Gerba [4], Benson [18].

About 0.1 ml of water sample was serially diluted in sterile distilled water and aliquots of the dilutions were aseptically plated into Nutrient Agar and Potato Dextrose Agar prepared according to manufacturer's instructions as described by Jorgensen et al. [19]. Sterilization media at standard conditions and fortification with anti-bacterial and anti-fungal agents (chloramphenicol) and (Nystatin) respectively was ensured. Samples were serially diluted up to 10^{-6} dilution and 1 ml of diluent was transferred to nutrient agar for spread culture. The agar plates were incubated inverted at 37°C for 24-48 h for THB and 30°C for 3-5 days for fungi to enumerate the aerobic and facultative microbes. The resultant growth/colonies on the plates were counted and expressed as colony forming units (cfu/ml).

Statistical analysis

The data obtained from this research of the physicochemical and heavy metals parameters and the log transformed microbial population Mean ± standard error data were expressed by one-way ANOVA using GraphPad prism software version 7 [20]. The mean results of the leachate characteristics are presented in **Tables 1-3** for Permissible limits for FEPA, DPR and WHO [21-23].

Results and Discussion

Comparative analysis by location

The total mean values of the leachate parameters measured in Onitsha dumpsite, unsullied agricultural soil and groundwater (probe samples) were obtained from a farmland 45.6km from Onitsha dumpsite to ascertain significant differences presented in **Table 1**. The data indicate heavy levels of pollution from leachate sample. The heavy industrial activities in the city might be directly linked to high pollution values from heavy metals like Cadmium, Silver, Aluminum, Molybdenum, Arsenic, Mercury, Manganese, Zinc, Copper, Nickel, Chromium, Magnesium, Iron, Lead and Cobalt. The values of heavy metals in leachate are shown in **Table 1** respectively. In Onitsha area, industrial activities like steel processing, waste combustion, immersion and freezing of food products, electrical works, roofing and plumbing works, paper production, painting works, bleaching are all accountable for heavy metals and chemical constituents with higher pollution values record. However, pH, conductivity, turbidity, % sand, % clay, % silt, color, total dissolved solid, temperature, total organic carbon, cation exchange capacity, in probe samples (probe samples) lead, nickel, chromium, and cadmium are values recommended as permissible by FEPA, DPR and WHO standard in **Table 3**.

Table 1 Chemical Properties of River water, Agriculture Soil and Ground Water.

Site Parameter	River water	Ground water	Soil	Unit
Cadmium	0.536 ± 0.001	0.24 ± 0.001	0.001 ± 0.001	ppm
Silver	0.023 ± 0.001	0.015 ± 0.0015	0.002 ± 0.001	ppm
Aluminium	0.003 ± 0.005	0.007 ± 0.006	0.002 ± 0.001	ppm
Molybdenium	1.121 ± 0.001	0.923 ± 0.001	0.003 ± 0.006	ppm
Arsenic	0.017 ± 0.015	0.003 ± 0.006	0.001 ± 0.001	ppm
Mercury	2.291 ± 0.001	0.002 ± 0.001	0.009 ± 0.001	ppm
Manganese	0.131 ± 0.001	0.542 ± 0.001	10.250 ± 0.001	ppm
Zinc	0.402 ± 0.001	0.187 ± 0.001	12.500 ± 0.001	ppm
Copper	0.027 ± 0.001	0.031 ± 0.001	4.260 ± 0.001	ppm
Nickel	0.027 ± 0.002	0.032 ± 0.001	2.421 ± 0.001	ppm
Chromium	0.017 ± 0.015	0.002 ± 0.001	0.002 ± 0.001	ppm
Magnesium	20.233 ± 0.001	18.717 ± 0.002	23.200 ± 15.588	ppm
Iron	0.215 ± 0.001	2.917 ± 0.001	10.200 ± 0.001	ppm
Lead	0.655 ± 0.001	0.197 ± 0.001	0.090 ± 0.001	ppm
Cobalt	0.363 ± 0.001	0.081 ± 0.001	0.081 ± 0.001	ppm

Results are Means of Triplicate Determination ± Standard Deviation (SD).

Table 2 Physico-Chemical Parameters of Ground Water and Agriculture Soil.

Site Parameter	Soil Sample	Parameters	River water Sample	Groundwater sample
pH	Mean ± SD 6.407 ± 0.015	Temperature (°C)	Mean ± SD 28 ± 1.0	_
Cation Exchange Capacity (Mol/kg)	0.015 ± 0.0001	pH	7.15 ± 0.01	6.57 ± 0.010
Total Organic Carbon (%)	0.160 ± 0.0001	Conductivity (µS/cm)	7.50 ± 0.01	7.75 ± 0.010
% sand	49.22 ± 0.015	Turbidity (Ntu)	74.3 ± 1.52	29.6 ± 0.577
% silt	27.00 ± 1.000	Color	Light grey	-
% clay	22.77 ± 0.010	Total Dissolved	1.06 ± 0.015	1.01 ± 0.050

Results are Means of Triplicate Determination ± Standard Deviation (SD).

Table 3 Permissible limits for FEPA, DPR and WHO.

Trace Metals	FEPA µg/g	DPR µg/g	WHO µg/g
Cd	0.01	0.01	0.005
Cr	0.03	0.03	0.02
Pb	0.05	0.05	0.05
Ni	0.1	0.1	0.5

Microbial and physicochemical concentration

The THB, total fungi from leachate sample obtained at the dumpsite in the Onitsha dumpsite of Nigeria. THB, and total fungi ranged from 6.23-9.79 Log cfu/ml, 5.25-6.64 Log cfu/ml, respectively, with significance difference ($P<0.05$). Higher counts of bacteria obtained in leachates were observed compared to the fungal count. *Serratia marcescene*, *Klebsiella aerogenes*, *Staphylococcus aureus*, *Alcaligens sp*. and *Proteus mirabilis* species were the bacteria genera isolated from the leachate samples and *Aspergillus niger*, *Aspergillus flavus*, *Rhizopus* and yeast species were the fungi isolates obtained from the leachates.

The physicochemical characteristics of the leachates obtained from the dumpsite as shown in **Table 1**. Triplicate mean values obtained from leachate and ground water (probe) are presented in **Table 1**. pH, conductivity, total dissolved solid, turbidity ranged from 7.15 ± 0.01-6.57 ± 0.010,7.50 ± 0.01-7.75 ± 0.010 µS/cm,74.3 ± 152-29.6 ± 0.577 mg/l, 1.01 ± 0.050 mg/l respectively of significantly different ($P<0.05$).

Leachate heavy metal concentration

Heavy metals concentration in the leachate from the sampling locations was analyzed for level of contamination index (**Table 1**) as compared to River water, ground water and soil using FEPA, DP and WHO. The result of the contamination index for leachate is a potential threat to ground water and interpretation according to the permissible limits indicates gross pollution degree. This demonstrates that the vicinity of Onitsha and discharged leachate possesses high heavy metal pollution index and a potential threat to human health living in the environment.

In our analysis, measured heavy metals in the leachate were measured to show significant high concentration in Onitsha due to anthropogenic implication in the area. Cd, Pb and Ni indicated high level of concentration due to the maximum allowable effluent discharge limit from industrial channels and also to the limit set by FEPA, DPR and WHO [21-23].

Previous studies have also mentioned significant increase in microbial population of leachate from Orita-aperin and Awotan dump sites reported by Sulaimon et al. [24], showed the range of 1.9×10^8 to 3.77×10^9 cfu/ml from sample obtained in Ibadan. High microbial load was also obtained from leachate in dumpsite at Ekiti-State Government Destitute Centre as reported by Odeyemi et al. [6] with total bacteria and fungi colony counts of 70.6×10^7 cfu/ml to 7.3×10^8 cfu/ml and 39.9×10^7 cfu/ml to 1.9×10^8 cfu/ml respectively. Runoff from dumpsites leachate may percolate into surface water and it could induce defilement. Therefore, the populate that derive their drinking water from such water body are exposed to high tendency of contacting causative agents of water borne diseases that could result in diarrhea, typhoid fever etc. Due to the high total coliform ratio of 10 cfu/ml, it has fallen below the maximum permissible limit for drinking water as specified by standard organization of Nigeria [25,26].

In view of all these, there is an urgent concern in the treatment of effluent before discharge to put an end to environmental pollution.

Conclusions

This study indicates significantly high level of Heavy Metals (Cd, Pb and Ni) concentration and moderate ratio of Cr in dumpsite leachate located at Onitsha, a town in Anambra state, southward eastward Nigeria as investigated. The results obtained showed that the soil and ground water samples from various site have a high level of heavy metals concentration as compared to the permissible limits **(Tables 1 and 3).**

High persistence of metals in soil originating from indiscriminate discharge of wastewater indicates high possibilities of these toxins and high level in food chain. Long term toxicological and biochemical effects due to proliferation and passage through food chain. Therefore, waste management and treatment are recommended and periodic of the soil for chemical toxins discharged from municipal and industrial waste.

The result showed a positive correlation between heavy metals and untreated effluent discharged into the dumpsite as well as significant difference in the standards and a major cause of such pollution level. These results emphasize on the necessity for better solid waste management in Onitsha with source segregation of hazardous municipal and industrial waste before disposal as well as enforcing regulations.

Acknowledgements

The authors would like to thank the Department of Applied Microbiology and Brewing, Nnamdi Azikiwe University, Nigeria for the use of their laboratory for microbial analysis. Special thanks to Springboard Research Laboratories for analysis of heavy metals.

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