Journal of Engineering Research and Reports

13(2): 11-19, 2020; Article no.JERR.57040
ISSN: 2582-2926

Leachate Characterization from Municipal Solid Waste Dump Site and Its Adverse Impacts on Surface Water Quality Downstream - Uyo Village Road, Akwa Ibom State - Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. This work was part of author SAN thesis work. Author MJA was a major supervisor. Authors AHI and RNO were co-supervisors. Author SAN did the study design, wrote the protocol, statistical analysis, literature searches, analyses of study, supervisors read and approved the final manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JERR/2020/v13i217096
Editor(s):
(1) Dr. David Armando Contreras-Solorio, Autonomous University of Zacatecas, Mexico.
Reviewers:
(1) Islam-ul-Haque, Pakistan.
(2) Carla Cristina Almeida Loures, Federal Center for Technological Education, Brazil.
Complete Peer review History: http://www.sdiarticle4.com/review-history/57040

Original Research Article

Received 15 March 2020
Accepted 20 May 2020
Published 01 June 2020

ABSTRACT

The present investigation discusses the characteristic of leachate generated from municipal solid waste landfill and it adverse impacts on downstream water quality. Landfill leachate was collected from a hole dug 10 m away from the waste dump site and the appearance of the leachate sample looks black. Three downstream water samples were collected at 10 meters intervals each from each other and less than 100 meters from the boundary of the dumpsite. All the samples were examined for temperature, pH, TDS, TSS, BOD, COD, nitrate, ammonia, Cu, Ni, Pb, Cd, Cl, total phosphate, sulfate, EC, DO and turbidity. The aim was to compare physicochemical and heavy metal properties of leachate and downstream water quality with internationally accepted protocols.

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The Laboratory analysis exhibited prevalence of high value of pH (8.513 ± 0.09), temperature(29.0 ± 0.0℃), turbidity (14.0 ± 0.41NTU), DO (0.167 ± 0.05 mg/l), COD (68.0 ± 0.33 mg/l), BOD_5 (324.0 ± 3.00 mg/l), EC (4463 ± 15.53 μs/cm), Total phosphate (62.358 ± 0.01 mg/l), Pb (0.31 ± 0.00 mg/l), Cd (0.06 ± 0.00 mg/l), Ni (0.355 ± 0.01 mg/l), and Cu (8.67 ± 0.04 mg/l) in the leachate sample, which have exceeded their permissible limits. For downstream water samples, pH (7.76 ± 0.07 to 7.507 ± 0.09), temperature (29.0 ± 0.00℃) for the three sampling points, DO (3.667 ± 0.15 to 3.233 ± 0.12 mg/l), total phosphate (8.225 ± 0.00 to 7.935 ± 0.02 mg/l), Pb (0.465 ± 0.01 to 0.091 ± 0.00 mg/l), Cd (0.04 ± 0.00 to 0.023 ± 0.00 mg/l), Ni and Cu (0.043 ± 0.06 mg/l) and (1.062 ± 0.00 mg/l) respectively, also exceeded their respective permissible limit recommended by Nigerian Standard for Drinking Water Quality, World Health Organization in drinking water quality. From this study, there is evidence that there is an increase in risk to surface water that is reported near Uyo village road municipal solid waste dumping site. Therefore, the concerned authority should take appropriate intervention measures to protect surface water. Also, knowledge of leachate quality will be useful in planning and providing remedial measures to protect downstream water quality in the area.

Keywords: Dumpsite; municipal solid waste; leachate; surface water; ground water; contamination.

1. INTRODUCTION

Groundwater is a valuable resource frequently used for industry, commerce, agriculture and most importantly for drinking. Often, the raw water used for domestic purposes is vulnerable to contamination due to human activities resulting in pollution. Groundwater pollution is mainly due to the process of industrial development and urbanization that has gradually developed over time without any esteem for environmental significances. In recent times, the effect of leachate on groundwater and other water resources has attracted a lot of attention because of its overwhelming environmental significance. The leachate from municipal solid waste dumping ground is a highly concentrated "chemical soup," so concentrated that small amounts of leachate can pollute large amounts of groundwater rendering it unsuitable for use for domestic water supply. In addition to potential carcinogens and highly toxic chemicals, municipal solid waste leachate contains a variety of conventional pollutants that render a leachate-contaminated surface and groundwater objectionable due to tastes and odors, reduced service life of appliances such as dishwashers, water heaters, plumbing, fabric. Groundwater protection is a major environmental issue. Once contaminated, groundwater may forever remain polluted without remedy or treatment.

Most streams and other water resources in the world are heavily polluted nowadays. There are limited lands accessible for solid waste dumping. The growing generation and buildup of wastes produce serious environmental, economic and social difficulties in both developed and developing countries [1]. Electronic goods, painting waste, used batteries, etc. when dumped with municipal solid wastes increase the heavy metals in dumpsites and dumping without adequate separation of hazardous waste can further elevate toxic environmental effects. Environmental impact of land filling of municipal solid waste can usually result from the run-off of the noxious compounds into surface water and groundwater which ultimately lead to water pollution as a result of percolation of leachate [2]. Presently the landfill leachate is gaining a serious attention in the developing countries like Nigeria and to a lesser extent in the developed world with relevance to its toxicity and harmful environmental externalities.

The process of municipal waste management in Nigeria involves a number of compounding and multidimensional measures, which includes; segregation, packaging/storage, collection, transportation, processing, resource recovering, recycling, disposal etc. [3,4]. Notwithstanding, the commonest method of waste disposal in Nigeria are landfill system, incineration, composting and anaerobic digestion and recycling [5]. Unfortunate, in developing nation like Nigeria adherence to this procedure are not wholesomely adhered to, as wastes are usually dumped hazardously in the bush or along the road. A study in 2003 by the Health and Demography Department of Nigerian National Population Commission indicated that only 14% of Nigerian have access to reliable household waste disposal system. It was also documented in literature that about 87% of Nigerian apparently used unsanitary disposal system [6]. These wastes could be transported by runoff into surface water or even infiltrates through the soil which they constitute major environmental problems like groundwater pollution [7].

2. LITERATURE REVIEW

Taylor R, et al. [8] upheld that for instance assessment, landfills are most identified with the pollution of groundwater by waste-derived liquids. However, any site where waste is concentrated, processed and stored, even for a short period of time, may be a potential point source of surface and groundwater contamination. Such processing facilities are often not well regulated or licensed and frequently occur in urban or semi-urban settings, where local water supply points may be impacted by these activities. Lee, GF et al. [9] maintain that approximately 75 per cent of the estimated 75,000 sanitary landfills pollute adjacent groundwater with leachate. Leachate derived from landfills, refuse dumps includes a wide range of contaminations, depending on the types of waste deposited.

Groundwater pollution is caused by the presence of unpleasant and unsafe substance and pathogens beyond certain limits. Much of the pollution is due to human activities like discharge of sewage, effluents and waste from domestic and industrial establishment. Also, the situation of surface and groundwater pollution is more pronounced during the rainy season owing to the rate of leachate infiltration, percolation and migration.

Landfills is one of the main threats to groundwater resources [10]. Waste placed in landfills are subject to either underflow or infiltration from precipitation. Areas close to landfills have great possibility of surface and groundwater contamination because of the potential pollution source of leachate originating from the nearby site. Such contamination of groundwater resource presents a substantial risk to local resource users and to the natural environment [8].

3. STUDY OBJECTIVES

The objectives of the study:

- To discuss characteristics of leachate generated from municipal solid waste dumpsite through physico-chemical and some heavy metal analysis and
- To determined its adverse impacts on surface water quality downstream.

4. MATERIALS AND METHODS

4.1 Study Area

The study was carried out at Uyo Village Road in Uyo local government area. The site being engulfed by gully erosion some years ago was adopted by the Akwa Ibom State government as erosion control measures to reclaim the site. Uyo is situated at 5.03° North latitude, 7.93° East longitude and 196 meters' elevation above the sea level. The average annual temperature in Uyo is 26.4°C. The rainfall here averages 2509 mm. Fig. 1 is map of the Uyo urban showing Uyo village road.

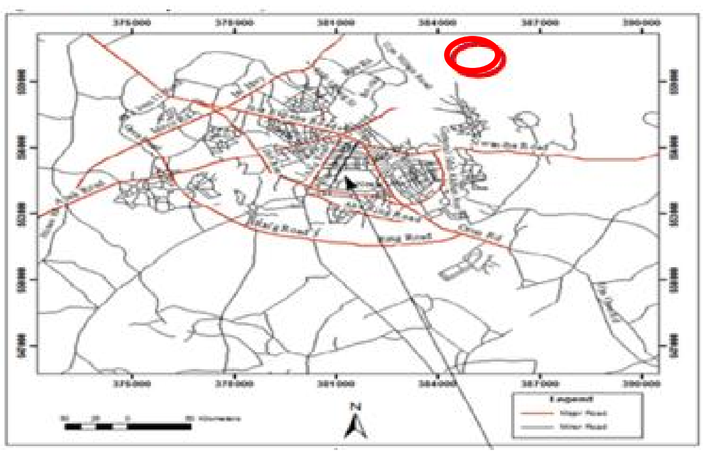

Fig. 1. Map of Uyo Urban

○ Uyo village road waste dumping site

4.2 Methodology

4.2.1 Sample collection and analysis

Before samples were collected, site selection for leachate and stream water samples was conducted. Landfill leachate was collected from a hole dug 10 m away from the waste dump site and the appearance of the leachate sample looks black to blackish brow. Three downstream water samples were collected at 10 meters intervals each from the point of contamination. This was found less than 100m from the boundary of the dumpsite. The samples were stored at a temperature of about 4°C in a refrigerator prior to analysis. Site specifications for sampling points are presented in Table 1.

The adopted methods of analyses for the examination of all parameters were in agreement with American Public Health Association [11] standard recommendation. Table 2 shows the parameters and instrument used to identify the parameters in the leachate and stream water samples.

4.3 Data Analysis

The data recorded from various tests were subjected to descriptive statistical analysis- mean and standard deviation. Results were compared with World Health Organization [12] and Nigerian Standard for Drinking Water Quality [13] to illustrate temporal variation of water quality parameters.

5. RESULTS AND DISCUSSION

The results of physico-chemical characteristics of leachate and far away stream water samples are presented in Table 3.

5.1 pH

The pH of the leachate sample determined was 8.51. This is probably due to the fact that leachate gets washed away by rainfall or percolated over time into the soil to a large extent. This means that the age and type of waste are the most important factors which affect the composition of leachate. The high pH in the

Table 1. Site specification for sampling

S/N	Sampling locations	Latitude and longitude	Type	Notation
1	Leachate Collecting Point	5°02ʹ 50.7’’ N; 7°56’07.4’’ E	Leachate	L
2	Stream Collecting Point	5.0512318°N; 7.9351829° E	Stream water	ST1
3	Stream Collecting Point	5.05201° N; 7.9344° E	Stream water	ST2
4	Stream Collecting Point	5.05071° N; 7.93424° E	Stream water	ST3

Table 2. Methods of analysis of different parameters of leachate and stream water samples

Parameters	Instrument used to identify the parameters
pH	Electronic pH meter
Temperature (℃)	Thermometer
Turbidity (NTU)	Turbidity meter
DO (mg/l)	DO meter
COD (mg/l)	Open reflux method
BOD (mg/l)	Winkler’s method
Electrical Conductivity (μs/cm)	Conductivity meter
TDS (mg/l)	TDS meter
TSS (mg/l)	TSS meter
Chloride (mg/l)	Titration
Sulphate (mg/l)	Titration
Nitrate (mg/l)	Spectrophotometer method
Ammonia (mg/l)	-
Total Phosphate (mg/l)	-
Lead (mg/l)	Absorption Spectrophotometer
Cadmium (mg/l)	Absorption Spectrophotometer
Nickel (mg/l)	Absorption Spectrophotometer
Copper (mg/l)	Absorption Spectrophotometer

Table 3. Physico-chemical characteristics and trace metal concentrations of the leachate and far away stream water samples

Details	Leachate (L1)	Stream (ST1)	Stream (ST2)	Stream (ST3)	NSDWQ (2015)	WHO (2011)
pH	8.513±0.09	7.76±0.07	7.69±0.02	7.507±0.09	6.5-8.5	6.5-8.5
Temperature(℃)	29.0±0.00	29.0±0.00	29.0±0.00	29.0±0.00	@	25
Turbidity (NTU)	14.0±0.41	1.70±0.17	1.467±0.06	1.0±0.00	5	@
DO (mg/l)	0.167±0.05	3.667±0.15	3.50±0.17	3.233±0.12	@	2
COD (mg/l)	68.0±0.33	1.367±0.06	1.30±0.10	1.133±0.15	@	<10
BOD_5 (mg/l)	324.0±3.00	0.5±0.1	0.467±0.15	0.433±0.06	@	0.8-5
E.C (μs/cm)	4463±15.53	270.0±1.16	269.0±1.73	236.0±1.53	1000	1000
TDS (mg/l)	0.0±0.00	0.693±0.01	0.01±0.00	0.01±0.00	500	@
TSS (mg/l)	1.633±0.12	1.30±0.02	1.287±0.01	1.287±0.01	@	3
Chloride (mg/l)	96.667±5.77	108±0.00	109.3±1.16	877±2.89	250	250
Sulphate (mg/l)	4.085±0.01	0.33±0.43	0.129±0.00	0.16±0.00	100	100
Nitrate (mg/l)	5.76±0.04	5.708±0.01	5.579±0.00	5.572±0.00	50	10
Ammonia (mg/l)	1.183±0.01	1.173±0.01	1.143±0.01	1.140±0.00	@	@
Total phosphate (mg/l)	62.358±0.01	8.225±0.00	8.169±0.00	7.935±0.02	@	5
Lead (mg/l)	0.31±0.00	0.465±0.01	0.406±0.00	0.091±0.00	0.01	0.01
Cadmium (mg/l)	0.06±0.00	0.04±0.00	0.029±0.00	0.023±0.00	0.003	0.003
Nickel (mg/l)	0.355±0.01	0.043±0.06	0.016±0.00	0.01±0.00	0.02	@
Copper (mg/l)	8.67±0.04	1.062±0.00	0.810±0.00	0.755±0.01	1	@

Values are Means and Standard Deviation of Triplicate
@ = Not found in the available WHO and NSDWQ standard documents

leachate indicates low metal solubility where the solubility generally decreases with increasing pH due to the precipitation of metal ions as insoluble hydroxides.

The pH values of the downstream water samples were found to be 7.76, 7.69 and 7.51. These variations in pH concentrations with increase in distance from the point of contamination of stream by the leachate may likely caused by surface run-off and dilution effects. Additionally, the influx of contaminants from municipal solid waste dumping ground and other land uses can also affect the pH values. However, these pH values were within what would be considered a relative band [14]. When compared with the Nigerian Standard for Drinking Water Quality [13] and World Health Organization [12] recommended range for pH in drinking water (6.5-8.5) are within the acceptable range.

5.2 Temperature

The temperature of the leachate and far away stream water samples was recorded as 29 ℃ which indicates the presence of foreign bodies such as active micro-organisms [15-17], reported that temperature of water is important parameter because of its effect on chemical reactions and reaction rates, aquatic life, and the suitability of the water for beneficial uses. The temperature of the downstream water samples is found outside [12] standard in drinking water quality 25℃. High temperature as is recorded in this study may leads to low dissolved oxygen level in surface/ground water.

5.3 Turbidity

The turbidity of the leachate sample collected from municipal solid waste dumping ground was recorded as 14 nephelometric turbidity units (NTU). The observed turbidity value in leachate may be due to the proximity to the landfill indicating a higher sediment flow. The permissible limit for turbidity in drinking water is 5nephelometric turbidity units (NTU) according to [13]. Turbidity of the downstream water samples were found to be 1.7, 1.47 and 1.0 nephelometric turbidity units (NTU). Values were within the recommended limit for drinking water quality when compared with [13].

5.4 Dissolved Oxygen

The value of 0.17 mg/l was an indication of oxygen depletion in leachate sample, which inferred the presence of pollutants that might have use up oxygen in water. Dissolved oxygen concentrations indicate whether aerobic or anaerobic conditions exist in surface/ groundwater and therefore provide useful information toassess the potential for biodegradation or biotransformation of chemical of potential concern. The primary reason for depletion of DO is the proliferation of oxygen-demanding aerobic bacteria.

The dissolved oxygen values of the stream water samples were found to be 3.67, 3.50 and 3.23 mg/l. Dissolved oxygen values were found outside the range for drinking water quality standard (2 mg/l) when compared with world health organization [12] which indicated that the stream was unsafe for consumption. Dissolved oxygen is essential to the survival of aquatic life [18]. One of the adverse effects of pollution of a water body is a decrease in dissolved oxygen. Decrease in dissolved oxygen is a positive indication of water pollution.

5.5 Chemical Oxygen Demand

The chemical oxygen demand in the leachate sample collected from the municipal solid waste dumping site recorded 68 mg/l. The present study indicates the presence of some recalcitrant organic constituents in the leachate.

The critical limit for COD in drinking water is less than 10 mg/l. The COD values of the stream water samples are found to be 1.37, 1.30 and 1.13 mg/l. The values are within the acceptable limit when compared with [12] standard in drinking water quality.

5.6 Biological Oxygen Demand

The biological oxygen demand of the leachate sample determined was 324 mg/l. These results is in line with the values obtained by [19], who determined the biological oxygen demand in the leachate samples which recorded 329, 495 and 406 mg/l for young (< 5 years), intermediate (5 to 10 years) and old (> 10 years) dumping sites of Ludhiana, respectively and he also quoted that the biological oxygen demand value varies according to age and waste composition of the dumpsites. The high biological oxygen demand value indicates the high organic strength in the leachate of the dumping site.

The critical limit for BOD_5 in drinking water is between 0.8 - 5.0 mg/l. The biological oxygen demand values of the stream water samples are found to be 0.5, 0.47 and 0.43 mg/l. The values are found lower than the acceptable limit according to World Health Organization [12], in drinking water quality.

5.7 Electrical Conductivity and Total Dissolved Solids

Electrical conductivity and total dissolved solids are generally influenced by the total amount of dissolved organic and inorganic materials present in the solution, and used to demonstrate the degree of salinity and mineral contents of leachate. The salt content in the leachate is due to the presence of potassium, sodium, chloride, nitrate, sulphate and ammonia salts. The electrical conductivity was recorded as 4463 μ s/cm as a consequence of degradation of organic matter.

When stream water samples are compared with the [12,13], recommended range for conductivity and TDS in drinking water found to be acceptable.

5.8 Major Anions: Chloride, Nitrate and Sulphate

Leachate sample was found to have low concentrations of all the major anions like chloride, nitrate and sulphate. The low chloride content in the leachate justifies low range of total dissolved solid and COD value in the present study. Sulphat in landfill leachate is source primarily from the decomposition of organic matter, soluble waste such as construction waste or ash, synthetic detergents and inert waste, such dredged river sediments. Nitrates are the end product of the biochemical oxidation of ammonia and nitrogen from organic matter. Stream water samples are within the acceptable range when compared with [4,5]. High chloride value in the stream water sample (ST3) justifies high range of total dissolved solids in the stream (ST3). This also indicates pollution requiring a treatment before use.

5.9 Ammonia

The ammonia value in the leachate was 1.18 mg/l provides evidence of its release from decomposition of nitrogenous substances in the dumping ground. There is no set standard for ammonia in leachate aimed for discharge into aquatic environment in [12,13] even though it is highly toxic and lethal to aquatic species even at low concentrations.

5.10 Total Phosphate

Total phosphate value for leachate was found to be 62.36 mg/l. Phosphate might have a variety of sources including agricultural fertilizers, domestic wastes, detergents, industrial process wastes etc. Phosphate values in stream water samples are found outside the acceptable limit according to [12] recommended value for drinking water quality. This may be due to the emission from mixed waste.

5.11 Heavy Metals

The metal analysis showed high concentrations of lead, cadmium, nickel and copper in the leachate which indicated the presence of toxic wastes coming perhaps from disposed off battery cells, used aerosol cans and other materials with a certain degree of toxicity. Lead and cadmium values of the leachate (L1) recorded as 0.31 and 0.06 mg/l. Stream water samples are found to be 0.465, 0.406 and 0.09 for Pb, 0.04, 0.029 and 0.023 mg/l for cadmium which is above the permissible limits 0.01 and 0.003 mg/l according to [12,13] standard for lead and cadmium in drinking water respectively, which is a clear manifestation of the presence of toxic waste in the landfill. Also, nickel and copper values of the leachate sample (L1) recorded as 0.35 and 8.67. Stream water samples are found to be 0.043, 0.016 and 0.01 mg/l for nickel and 1.06, 0.81 and 0.75 mg/l for copper which is also above the permissible limit according to [13] 0.02 mg/l for nickel and 1.0 mg/l for copper. These trace elements are considered to be dangerous pollutant. Such contamination of surface water may result in a substantial risk to local surface/groundwater resource users. In a living system they are capable of disrupting normal functions of a cell by virtue of their capacity to form strong metallic bonds with a number of functional macromolecules at the same time causing clump formation. Lead cause anemia, brain damage, anorexia, mental deficiency, vomiting and even death in human beings [20,21] and is toxic even at lower concentrations. Cadmium has been reported to cause agonistic and antagonistic effects on hormones and enzymes leading to lots of malformations like renal damage [22,23] and are toxic at low concentrations [24]. Cadmium and lead have also been classified as carcinogens [25,13]. Other trace metals such as nickel and copper have also been reported for various health problems with possibility of bio-accumulation in the food web.

6. CONCLUSION

The leachate collected from Uyo village road municipal solid waste dumping ground demonstrates/prevalence of exceedingly high values of almost all the physico-chemical and heavy metals/elements. Hence the leachate is considered to contain significant loads of contaminants which may pose threat to the underlying surface/ground water aquifer. Most of the physico-chemical and heavy metal properties of faraway stream water samples exceed their respective permissible limits. This shows evidence of contamination of downstream water quality by the leachate. Therefore, the concerned authority should take appropriate intervention measures to protect surface water. Also, knowledge of leachate quality will be useful in planning and providing remedial measures to protect downstream water quality in the area.

7. RECOMMENDATIONS

The following recommendations are made with due considerations to the above findings:

1. Monitoring of these sites is recommended as well as research by biomedical experts to reveal the exact adverse effects that physiochemical and heavy metal contamination of water might induce in humans, particularly among individual in vulnerable population.
2. Local authorities should be made aware of such health risks and provide potable water facilities either by treating the water or find alternative sources for drinking.
3. Local people using stream water as drinking water source, especially around municipal solid waste dumping site, need to be educated about the potential adverse effects of drinking directly from stream water.
4. Continuous monitoring and further studies of the area are recommended to ascertain long-term effects.
5. Further investigation is also recommended for seasonal variability of toxic metals in the study area.
6. Finally, there is need for design and construction of sanitary landfill in the study area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/57040