**_Original research paper_**

# Influence of the composition of the municipal solid waste (MSW) on the physicochemical parameters of leachate at the municipal solid waste landfill in Nkolfoulou –Yaounde.

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## ABSTRACT

This study highlights the influence of the composition of the municipal solid waste (MSW) on the physicochemical parameters of leachate at the municipal solid waste landfill in Nkolfoulou –Yaounde. Toxicity characteristic leaching procedure (TCLP) was used as a chemical and analytical method for soil sample extraction to simulate leaching through a landfill. During TCLP procedure the pH of the sample material was first established, and then leached with an acetic acid / sodium hydroxide solution at a 1:20 mix of sample to solvent. Electrical conductivity (EC) was determined using conductivity meter; Total Suspended Solid (TSS), Chemical Oxygen Demand (COD), Biological Oxygen Demand. (BOD) were determined using standard procedures. Phosphate was analyzed calorimetrically and heavy metals (Cu, Fe, and Manganese) by Graphite Furnace Atomic Absorption Spectrometric Method. Pearson's correlation using Statistical Package for Social Sciences (SPSS) version 20.0 .was used to estimate the degree of association between waste components and leachate parameters. The results indicate a strong influence of solid waste on leachate production and composition. We found a strong positive correlation between paper and Total Suspended Solids (TSS), r = 0.7724, Phosphorus, r = 0.7249, Fe, r = 0.6993 and Cu, r = 0.7249



*Keywords: Solid waste; leachate; landfill; Heavy metal.*


## 1. INTRODUCTION

The social and environmental impacts imposed by Municipal solid waste (MSW) received attention in recent decades [1]. Therefore, several policies, strategies, plans and methods have been developed in the field of MSW management. These include waste reduction and waste recovery for reuse, recycling, composting and incineration for energy generation in addition to landfilling of final rejects [2]. Notwithstanding, only very few waste characterization studies have been carried out in landfills in many developing countries to ascertain the relationship between leachate parameters and MSW components. Municipal solid waste is considered as those wastes that arise from households as well as wastes that do not contain hazardous materials originating from other producers whose nature and composition resembles wastes arising from households [3]. Solid wastes are generally disposed of to landfill, because landfill is the cheapest and most-cost effective method of disposing of waste [4].

In most low to medium income developing nations, almost 100% of generated waste goes to landfill. Even in many developed countries, most solid waste is landfilled [5]. However, the difference between the developing and the developed countries is the approach with the dramatic shift from landfilling to sanitary landfill being practiced in many developed countries because it can achieve the recovery of derelict land [6]. In addition to this are financial constraints, with many municipalities in the developing countries predominantly involved in landfilling which is achieved by trench method. Daily, the supplied solid waste is weighed at the landfill site, dumped into the cell, compacted and covered with soil layer to abate fire risk, decrease landfill odors, and diminish windblown garbage. Covering the waste with soil consumes a significant volume of cell capacity. Also, these soil layers reduce the velocity of leachate movement within the cell and hence may cause localized leachate trapping within the cell. Therefore, soil covering layer is removed, leaving a small depth of sand on top of the existing waste. The new waste is then placed above this layer of soil. The waste covering and de-covering events take place every day till the cell is totally filled [7, 8]. Although the quantity of waste to landfill may in future decrease, the total volume of MSW being produced is still increasing significantly, in excess of 3% per annum for many developed nations [9]. In the same light [10, 11].indicated that the linear increase is due to resource consumption resulting in huge volumes of solid waste from various kinds of industries and domestic activities, with significant threat to human health and the environment from leachate.

The generation of leachate is caused mainly by precipitation percolating through waste deposited in a landfill. Once in contact with decomposing solid waste, the percolating water becomes contaminated, and if it then flows out of the waste material it is termed leachate. Additional leachate volume is produced during decomposition of carbonaceous material producing a wide range of other materials including methane, carbon dioxide and a complex mixture of organic acids, aldehydes, alcohols and simple sugars. Leachate quality is largely influenced by waste characteristics, waste composition and age. For instance, young leachate (1–2 years) is characterized by high organic fraction of relatively low molecular weight such as volatile organic acids, high chemical oxygen demand (COD), total organic carbon (TOC), biological oxygen demand ($BOD_5$) and a $BOD_5$/COD >0.6 [12]. In contrast, old leachate (>10 years) is characterized by a relatively low (COD) (<4,000 mg/L), slightly basic (pH > 7.5) and low biodegradability ($BOD_5$/COD <0.1) [13]. Other factors include, site operation methods such as compaction level, daily cover, pretreatment, liquid waste co-disposal, and quality and quantity of water entering the landfill. The type and concentration level of the contaminants in the leachate also depend on the manner of waste segregation before its final disposal [14]. The leachate problem is worsened by the fact that many landfills in developing countries lack appropriate landfill facilities, such as bottom liner, leachate collection, and treatment systems; this increases the possibility of groundwater and surface water contamination [15]. Landfill leachates are thus expected to remain a relevant source of ground and surface water contamination for the foreseeable future [16].Dangerous chemicals like Polycyclic Aromatic Hydrocarbons (PAHs) and organic micro pollutants often found in leachate are assimilated by aquatic species, plants and passed through food chain and bioaccumulate in human on long term exposure [17]. Exposure to toxic substances to populations residing near contaminated dumpsite, has led to series of human health disorders which include organ dysfunction, agonistic and antagonistic effect, anemia, reproductive, neurobehavioral and genetic disorders [18, 19]**.** This study highlights the influence of the composition of the MSW on the physicochemical parameters of leachate at the municipal solid waste landfill in Nkolfoulou -Yaounde.

## 2. MATERIAL AND METHODS

### 2.1 Study Area

The Yaoundé municipal landfill is located at Nkolfoulou Village (Soa Sub Division, Mefu and Afamba Division), 25km from the city centre in the North Eastern part of Yaoundé [20]. This 56-hectare piece of land sited in the valley of the Foulou River was acquired through consultations between the villagers of Nkolfoulou and the Yaoundé City Council in the late 1980s and came to use in 1990. It replaced the old sites at Ngousso and Nkolewoe. The landfill is a state utility managed by a private company, HYSACAM (Hygiène et Salubrité du Cameroun), the officially contracted company that is responsible for collecting and treating municipal solid waste in Yaoundé. The major attractions of the site is its location (2km away from nearest residential areas), large size (allowing use for at least 20 years), gentle slope (permitting natural flow of leachate) and sufficient lateritic soil (to cover waste) [21]**.** Figure 1 shows the site topography and distribution of various service zones within the landfill area. Waste recovery (Zone 2) and solid waste treatment by landfilling (Zone 4) were together envisaged as important aspects of the waste treatment.

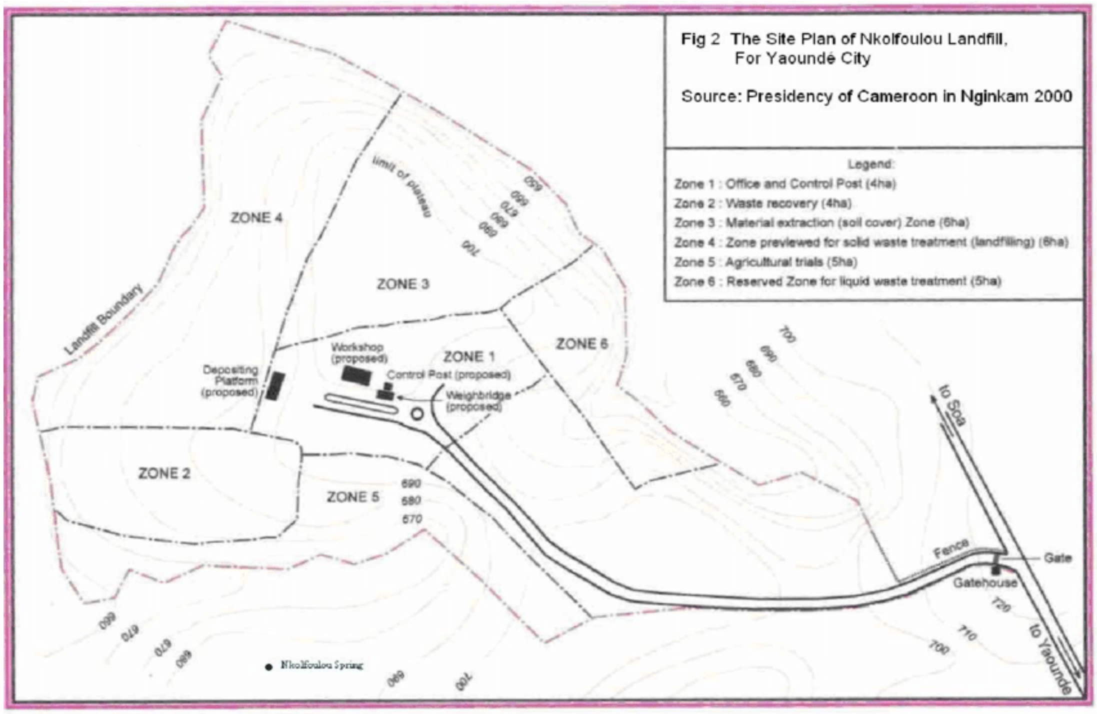


**Fig. 1.** **Site Plan of Nkolfoulou Landfill**

### 2.2 Sample collection and sampling

Toxicity characteristic leaching procedure (TCLP) was used as a chemical and analytical method for soil sample extraction to simulate leaching through a landfill. Toxicity characteristic leaching procedure (TCLP) was used. TCLP is a testing methodology to determine if a waste is characteristically hazardous, i.e., classified as one of the "D" listed wastes by the U.S. Environmental Protection Agency (EPA).

TCLP comprises four important procedures [22]

- Sample preparation for leaching
- Sample leaching
- Preparation of leachate for analysis
- Leachate analysis

The soil samples were collected in polyethylene containers of 5.0L from two sites designated as (dumpsite and control site) using a core sampler at depth of 20 cm from an area of 20 cm diameter.

In the TCLP procedure the pH of the sample material was first established, and then leached with an acetic acid / sodium hydroxide solution at a 1:20 mix of sample to solvent. The leachate was then filtered so that only the solution (not the sample) remained, preserved and stored at 4 $^{0}$C in an ice cooling box and then transferred to the laboratory for analysis.

The pH of the sample was determined using glass electrode method with a standard calibrated pH meter. Electrical conductivity (EC) was determined using conductivity meter; Total Suspended Solid (TSS), Chemical Oxygen Demand (COD), Biological Oxygen Demand. (BOD) were determined using standard procedure [23]. Phosphate was analyzed calorimetrically [24]. Analysis of heavy metals (Cu, Fe, and Manganese) was carried out with Graphite Furnace Atomic Absorption Spectrometric Method.

#### 2.2.1 Statistical Analysis

Pearson's correlation using Statistical Package for Social Sciences (SPSS) version 20.0 was used to estimate the degree of association between waste components and leachate parameters. Correlation analysis is a preliminary descriptive method for estimation of the degree of association among the variables involved [25].

## 3. RESULTS AND DISCUSSION

### 3. 1 Leachate characterization

The results of physical and chemical analysis of the leachates are presented in Table 1.

**Table 1. Characterization of the leachates from Nkolfoulou landfill and control site**

| Parameters | Unit | Dumpsite values | Control site values | WHO [26] standards |
|---|---|---|---|---|
| pH | -- | 10.1 | 9.5 | 6.5-8.5 |
| Electrical Conductivity (EC) | µS/cm | 31.00 | 38.80 | -- |
| Total Suspended Solids (TSS) | mg/l | 112 | 193.3 | -- |
| Chemical Oxygen Demand (COD) | mg/l | 261.2 | 261.2 | -- |
| Biological Oxygen Demand (BOD) | mg/l | 20.1 | 20.1 | 50 |
| Phosphates | mg/l | < 0.05 | < 0.05 | 5 |
| Copper | mg/l | < 0.05 | < 0.05 | < 0.2 |
| Iron | mg/l | 0.05 | 0.05 | 20.00 |
| Manganese | mg/l | < 0.02 | < 0.02 | <5.0 |

#### 3.1.1 pH

The pH value for the landfill (dumpsite) leachate was 10.1 (Table 1), higher than the control site 9.5. The pH value of the leachate was significantly alkaline 10.1. In another research, [27] reported that the alkaline pH values in leachate represented biological stabilization of the organic components. This value exceeds WHO regulatory standards of 6.5-8.5. According to [17], the pH discrepancy can impede or completely wipe out all biological processes and resultant pollution of the surrounding environment.

#### 3.1. 2 Electrical conductivity (EC)

Conductivity is the measure of a substance to accommodate the transport of an electric charge [28]**.** Conductivity values for dumpsites were 31.0 μS/cm and 38.80 μS/cm for the control site. The high concentration of EC can be attributed to the presence of inorganic components, mainly high levels of various anions and the soluble salts [25] and [29] indicates that chloride, sodium and potassium contribute primarily to conductivity. Our result is in line with [30] who found that the conductivity of the leachate from the landfill in Malaysia was 31.68 μS/cm.

#### 3.1.3 Total Suspended Solids (TSS)

The increase in TSS revealed that the leachates contain high proportion of contaminants. The implication is that significant amount of dissolved inorganic materials are present in the dumpsite and could be harmful when it finds its way into living organisms. If this trend continues, it may lead to pollution of agricultural soils, vegetation and underground water within affected community [17].

#### 3.1.4 Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD)

The higher concentration of COD (261.2 mg/l) and BOD 20.1 mg/l observed for the dumpsite leachates showed that the dumpsite was particularly high in organic contaminants. The dumpsite had actively decomposing wastes which include pollutants that are soluble in water. Surface water entry into the dumpsite influenced solublisation of pollutants that accumulated and contaminated surrounding soil and underground water.

#### 3.1.5 Phosphates

The presence of PO4, in leachate is dangerous as it increase eutrophication and promote the growth of algae [28]. The dumpsite and control site values of 0.05mg/l fell within the WHO acceptable standard. Our results are also in line with [28] who carried out characterization and environmental assessments of leachates generated around solid waste disposal Sites in Port Harcourt, Nigeria.

### 3.1.6 Heavy metals

The heavy metals identified from leachate analysis included Copper (cu), Iron (Fe) and Manganese (Mn). Fe and Mn are less common heavy metals and can well be described as inorganic macro components. Copper and Iron registered values of 0.05 mg/l and manganese 0.02 which fall within acceptable standards of WHO. A slightly higher value for Mn (<0.030–0.165 mg/l) were obtained by [31] who studied composition and toxicity of leachates from a MSW landfill in Colombia.

### 3.2 Characterization of solid waste

A waste characterization involving direct observation and random sampling from 4 locations identified 6 major solid waste fractions. Putrescible waste had the highest average percentage composition (54.3%), followed by plastics (17.4%), textile (16.6%), cardboard / paper (8.8%), Waste Electrical and Electronic Equipment's (WEEE) (1.6%) and metal (1.3).

### 3.3 Correlation analysis between solid waste components and leachate parameters

From the results of a correlation between the solid waste fractions and the leachate parameters (Table 2) we found a strong positive correlation between paper and Total Suspended Solids (TSS), r = 0.7724, Paper and Phosphorus, r = 0.7249, paper and Fe, r = 0.6993 and paper and Cu, r = 0.7249. There was also a strong positive correlation (r = 0.9933) between Iron and Copper. . Notwithstanding, we found a negative correlation between putrescible waste and paper, r = -0.7001, plastic, r = -1, metal, r = -0.999, WEEE, r = -1 and Textile, r = -0.9985.

**Table 2. Pearson's correlation analysis between waste components and leachate parameters**

| 0 | TSS | P | Fe | Cu | Paper | Plastic | Metal | WEEE | Textile | Putrescible | Ph |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **TSS** | 1 | | | | | | | | | | |
| **P** | **0.9975** | 1 | | | | | | | | | |
| **Fe** | **0.9942** | **0.9993** | 1 | | | | | | | | |
| **Cu** | **0.9975** | 1 | **0.9933** | 1 | | | | | | | |
| **Paper** | **0.7724** | **0.7249** | **0.6993** | **0.7249** | 1 | | | | | | |
| **Plastic** | 0.0818 | 0.0107 | -0.0257 | 0.0107 | **0.6966** | 1 | | | | | |
| **Metal** | 0.0711 | 0 | -0.0364 | 0 | 0.6889 | **0.9999** | 1 | | | | |
| **EEE** | 0.091 | 0.0199 | -0.0165 | 0.0199 | 0.7032 | 1 | **0.9998** | 1 | | | |
| **Textile** | 0.0327 | -0.0385 | -0.0748 | -0.039 | 0.6605 | 0.9988 | 0.9993 | **0.9983** | 1 | | |
| **Putrescible** | -0.087 | -0.0161 | 0.0203 | -0.016 | -0.7001 | -1 | -0.999 | -1 | -0.9985 | 1 | |
| **Ph** | -0.973 | -0.9543 | -0.9429 | -0.954 | -0.8976 | -0.3089 | -0.299 | -0.318 | -0.2618 | 0.3141 | 1 |

## 4. CONCLUSION

The study was aimed at investigating the Influence of the composition of the municipal solid waste (MSW) on the physicochemical parameters of leachate at the municipal solid waste landfill in Nkolfoulou –Yaounde. The average concentration of heavy metals in leachate was observed in trace quantities. The negative correlation of pH with Fe, Cu and Mn indicated a strong connection of leachate's pH with heavy metals concentration. The high value of pH and EC and low heavy metals concentration is due to the fact that the landfill is in methanogenic stage. The low values for iron obtained in the leachate samples indicate the presence of very small quantities of iron and scrap metals at the dumpsite whose recovery, recycling and reuse by scavengers must have had a significant influence.

## REFERENCES


1. Calvo F, Moreno B, Zamorano M, Szanto M. Environmental diagnosis methodology for municipal waste landfills. Waste Manage. 2005; 25:768–79.
2. Narayana T. Municipal solid waste management in India: from waste disposal to recovery of resources. Waste Manage. 2009; 29:1163–6.
3. Słomczyńska B, Słomczyński T. Physico-Chemical and Toxicological Characteristics of Leachates from MSW Landfills. Polish Journal of Environmental Studies. 2004; 13: 627-637.
4. Barrett A, Lawlor J. The Economics of Waste Management in Ireland, Economic and Social Research Institute, Dublin; 1995.
5. Taylor R, Allen A. Waste disposal and Landfills: Potential hazards and information needs. In 2006 World Health Organisation, Protecting Groundwater for Health: Managing the quality of drinking water sources. Published by IWA Publishing, 2006; London, UK.
6. Erses AS, Fazal MA, Onaya TT, Craig WH. Determination of solid waste sorption capacity for selected heavy metals in landfills. J Hazard Mater. 2005; 121:223–32.
7. Ole H, Lizzi A, Jette BH. Leachate emission from landfill. In Final Report Swedish Environmental Protection Agency; Naturvårdsverket: Stockholm, Sweden, 2000; ISSN 1102-6944. Available online: https://www.naturvardsverket.se/Documents/publikationer/afr-r-265-se.pdf?pid=4394 (accessed on 10 October 2016).
8. Integral Consult. Environmental impact assessment: Al- Hammam landfill project.<http://www-wds.worldbank.org/external/default/WDSContent Server/WDSP/IB/2006/02/21.

9. Douglas T. Patterns of Land, Water and Air Pollution by waste. In Managing the Human Impact on the Natural Environment (ed. M. Newson), John Wiley & Sons, New York, 1992; pp 150-171.
10. Pariatamby A, Tanaka M. MSW Management in Asia and the Pacific Islands-Challenge and Strategic Solution; Environmental Science and Engineering, Springer: Singapore, 2014.
11. Ziadat AH, Mott H. Assessing solid waste recycling opportunities for closed campuses. Manag. Environ. Qual. 2005. [CrossRef].
12. Umar M, Aziz H, Yusoff MS. Trends in the use of Fenton, electro-Fenton and photo-Fenton for the treatment of landfill leachate. Waste Manag. 2010; 30:2113–2121.
13. Li W, Hua T, Zhou Q, Zhang S, Li F. Treatment of stabilized landfill leachate by the combined process of coagulation/flocculation and powder activated carbon adsorption. Desalination. 2010; 264:56–62.
14. Hassan AH, Ramadan MH. Assessment of sanitary landfill leachate characterizations and its impacts on groundwater at Alexandria. J Egypt Public Health Assoc. 2005; 80:27–49.
15. Kanmani S, Gandhimathi R. Assessment of heavy metal contamination in soil due to leachate migration from an open dumping site. Appl. Water Sci. 2013; 3:193–205. [CrossRef]
16. Allen AR. Containment Landfills: The myth of sustainability. Journal of Engineering Geology. 2001; 60: 3-19.
17. Adewuyi and Opasina. Physicochemical and Heavy Metals Assessments of Leachates from Aperin Abandoned Dumpsite in Ibadan City, Nigeria. E-Journal of Chemistry 2010; 7(4)12:78-1283.
18. Palmer SR, Dunstan FDJ, Fielder H, Fone DL, Higgs G, Senior ML Environ Health perspective. 2005; 113: 1362-1365.
19. Ogundiran OO, Afolabi TA. Assessment of the physicochemical parameters and heavy metals toxicity of leachates from municipal solid waste open dumpsite, Int. J. Environ. Sci. Tech. 2008; 5 (2): 243-250.
20. Ako A A, Elambo G N, Pivaga E N, Joseph N, Gatien B. Proceedings of 36th IAH Congress, October, 2008 Toyama, Japan Integrating Groundwater Science and Human Well-being.
21. Achankeng E. Sustainability in municipal solid waste management in Bamenda and Yaoundé, Cameroon. PhD Thesis, 2004. Adelaide University, Australia. 180pp.

22. Environmental Protection Agency (EPA).Toxicity Characteristic Leaching Procedure (Report). Washington, DC: U.S. Part of "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods." Document no. SW-846; July 1992.
23. APHA, American Water Works Association and Water Pollution Control Federation, Standard Methods for Water and Waste Water, 15th Ed. American Public Association,New York. USA, 1981.
24. Jonnalagadda SB, Mathuthu AS, Odipo RW, Wandiga SO. Chem Soc Ethopia.1991;5: 49-64.
25. Maiti SK, De S, Hazra T, Debsarkar A, Dutta, A. Characterization of Leachate and Its Impact on Surface and Groundwater Quality of a Closed Dumpsite - A Case Study at Dhapa, Kolkata, India. Procedia Environmental Sciences. 2016; 35:391–399.
26. WHO (World Health Organization) Revision of the WHO Guidelines for Water Quality Report of the First Review Group Meeting on Inorganics, (Netherlands) World Health Organization Geneva WHO/PEP/91.18,1991.
27. Fatta D, Papadopoulos A, Loizidou M. A study on the landfill leachate impact on the groundwater quality of the greater area. Environmental Geochemistry and Health. 1999; 21:175–190.
28. Nwankwoala and Onukogu. Characterization and Environmental Assessment of Leachates Generated Around Solid Waste Disposal Sites in Port Harcourt, Nigeria. Sumerianz Journal of Scientific Research. 2018; 1(2): 34-40.
29. Paul, TW. Waste Treatment and Disposal, Landfill Leachate 2 ed ed. The University of Leeds UK: John Wiley & Sons; 2004.
30. Bahaa-eldin EAR, Yusoff I, Samsudin AR, Yaacob WZW, Rafek AGM. Deterioration of groundwater quality in the vicinity of an active open-tipping site in West Malaysia. Hydrogeol J. 2010;18: 997–1006.
31. Olivero-Verbel J, Padilla-Bottet C, De la Rosa O. Relationships between physicochemical parameters and the toxicity of leachates from a municipal solid waste landfill. Ecotoxicol Environ Saf. 2008; 70:294–9.