

**Original research paper**  
**Leachates Characterization at the municipal  
solid waste landfill in Nkolofoulou -Yaounde,  
Cameroon**

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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 Nkolofoulou –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.

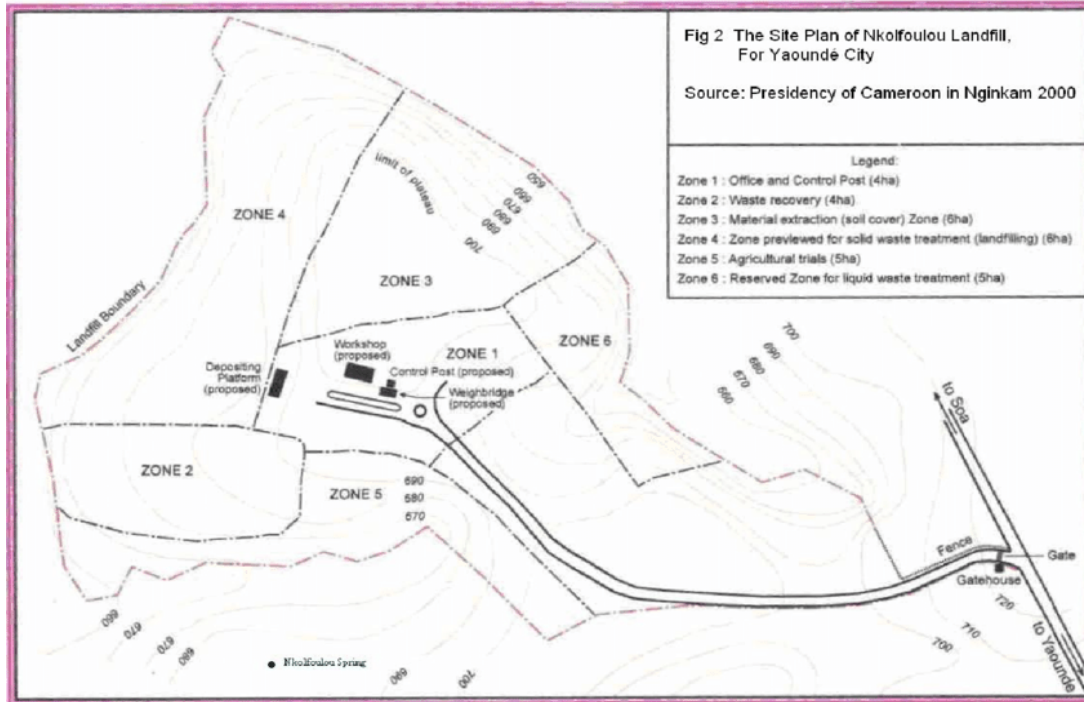
The generation of leachate is caused mainly by precipitation percolating through waste deposited in a landfill. Once in contact with decomposing solid waste, the percolating water becomes contaminated, and if it then flows out of the waste material it is termed leachate. Additional leachate volume is 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 Ngouso 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 2 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. 2. 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 °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 Nkolofoulou landfill and control site**

<b>Parameters</b>	<b>Unit</b>	<b>Dumpsite values</b>	<b>Control values</b>	<b>site WHO standards [26]</b>
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	-
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### **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  $\mu\text{S/cm}$  and 38.80  $\mu\text{S/cm}$  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  $\mu\text{S/cm}$ .

### **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 solubilisation of pollutants that accumulated and contaminated surrounding soil and underground water.

### **3.1.5 Phosphates**

The presence of  $\text{PO}_4$ , 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). Copper and Iron registered values of 0.05 mg/l and manganese 0.02 mg/l 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. The low values of heavy metal obtained may be attributed to the dumping of municipal waste and small quantities of industrial wastes. The low values for iron obtained in the leachate samples indicate the presence of very small quantities of iron and steel scraps waste in the dumpsite [18]. Recovery, recycling and reuse of iron and scrap metals by scavengers at the residential neighborhoods of Soak in Yaounde was also partly responsible for the small quantities of iron and scrap metals at the Nkolfoulou landfill.

### **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**

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

#### 4. CONCLUSION

In the developing country like Cameroon with a big knowledge gap in landfill management, landfills are more of an environmental, social and economic problem to the service provider HYSACAM, municipal authorities and the population in particular. The notion of sanitary landfill is good but not being practiced in many municipalities in Cameroon. It is for this reasons that HYSACAM should work in synergy with other stakeholders to create a recycling plant for the non-biodegradable waste fractions and a composting plant for the biodegradable waste fractions. This will provide an opportunity for resident to reap the benefits of the solid waste as a resource. A leachate treatment facility will be an added value to treat toxic substances in the leachate before it enters the aquatic and terrestrial environments.

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