

Hazardous Impacts of Open Dumpsite of Municipal Solid Wastes on Soil: Case of M'Ploussou Park Dump at Bonoua in Ivory Coast*

Bongoua-Devisme A. J.¹✉, Gueable Y. K. D.¹, Balland Bolou Bi C.², Bolou Bi B. E.¹, Kassin K. E.³, Adiaffi B.⁴, Yao-Kouame A.¹, Djagoua E. M. V.⁵

¹Département des Sciences du Sol, UFR Sciences de la Terre et des Ressources Minières, Université Felix Houphouët-Boigny, Cocody, 22 BP 582 Abidjan 22, Côte d'Ivoire

²Institut de l'écologie et des Sciences de L'environnement de Paris, UMR BIOEMCO, Université de Paris Est Créteil, 61 Avenue du Général de Gaulle, 94010 Créteil Cedex, France

³CNRA (Centre National de Recherche Agronomique), Côte d'Ivoire

⁴Département des Sciences et Techniques de l'Eau et de l'Environnement (DSTEE), UFR des Sciences de la Terre et des Ressources Minières, Université Félix Houphouët Boigny de Cocody, BP 582 Abidjan 22, Côte d'Ivoire

⁵CURAT (Centre Universitaire de Recherche et d'Application en Télédétection), Université Felix Houphouët-Boigny, Cocody 22 BP 801 ABIDJAN 22

*Impacts dangereux des décharges municipales à ciel ouvert sur le sol : Cas de la décharge du Parc de M'Ploussou de Bonoua, Côte Ivoire

ABSTRACT: In Ivory Coast, most of the uncontrolled dumpsites are open-air and is one of the most common methods adopted. To study the impact of the solid waste on soil, soil samples were collected from the dumpsite of M'Ploussou Park in Bonoua. The physical and chemical parameters such as size particle, pH, Exchangeable cations, CEC and the contents in heavy metals, were studied using various analytical techniques. It has been found that most of all the heavy metals analyzed contents exceeds the permissible limits in accordance with CCME soil quality standards. It's conclude that M'Ploussou Park dumpsite is characterized as polluted site whose the contamination is due to the solid waste materials that are dumped in the area.

Keywords: Solid Waste, Open Air Dumpsite, Heavy Metals, Bonoua

Introduction

In Ivory Coast, most of the dumpsites are open-air (Kouamé and *al.*, 2006) and is one of the most common methods adopted since years in almost all the cities, due to the low budget for waste disposal and non-availability of trained manpower (Hakkou and *al.*, 2001). These last decades, the rapid rate of industrialization, population and modernization have contributed to generate million tons of solid wastes of different categories (hazardous wastes, non-hazardous wastes) which are generally constituted of both the degradable and non-degradable substances (Praveena and Rao , 2016). These solid wastes may contain several heavy metals or metalloids which could poses severe environmental threat (Partha and

al., 2011) particularly affected groundwater resources and soil quality (OJEC, 2001). According to Mor and *al.*, (2006) and ISWA, (2015), dumpsites have been identified as one of the major environmental risk related to unsanitary landfilling of solid waste.

Solid wastes pollutants can affect the physico-chemical characteristics of soil ultimately contributing towards the contamination of plant as observed by Partha and *al.*, (2011) on dumpsite of india. The higher intensity of the contaminants can cause adverse effects on human health, animals and sometimes endanger the survival of some species (Papageorgiou, 2006; Akpaki and *al.*, 2014). In fact, several wastes from different sources find the way

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Bongoua-Devisme A. J. (Correspondence)



bongoua_jeanne @ yahoo.fr



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into the environment and finally end up in the dumpsites posing severe contamination of soil due to the heterogeneity. Soils serve as a natural sink for the pollutants released from both natural and man-made sources (Praveena and Rao, 2016). However, the assessment of soil pollution depends to the different sources where the contaminants belong. Therefore, it is utmost important to know the contamination degree of the open dumpsite of the park M'Ploussou of Bonoua situated at the heart of city, to prevent possible sanitary risks for the users and the dwellers. The aim of this paper is to have an exact knowledge of the nature of the contaminant present in the dumpsite of the M'Ploussou park in Bonoua.

MATERIALS AND METHODS

Study area

The study area is situated in the South-East part of Ivory Coast at Bonoua, 60 km to Abidjan, between latitude 5°14' to 5°31' N and longitude 3°13' to 3°51' W. The Dumping site is located in the M'Ploussou

Park, Bonoua at latitude 5°16' N and longitude 3°36' W (Fig. 1). This Dumping site has been abandoned since 2006 and covers an area of 16 ha. One kind of waste are dumped in this site: solid municipal waste.

The control site is situated at 5 km of dumping site at latitude 5°15' N and longitude 3°35' W.

The study area is located in tropical climate and has mean annual rainfall of about 2000 mm (Aké, 2010) with a rainy season (May to July and September to October) and a dry season (July to August and December to April). Geology of area is dominated by the sedimentary formations specially detritics rocks. The average monthly temperature of Bonoua is above 20°C.

The soil of study area is classified as an arenic ferralsol and the dumping site is classified as a Fumic Anthrosol in the World Reference Base for Soil Resources (WRB).

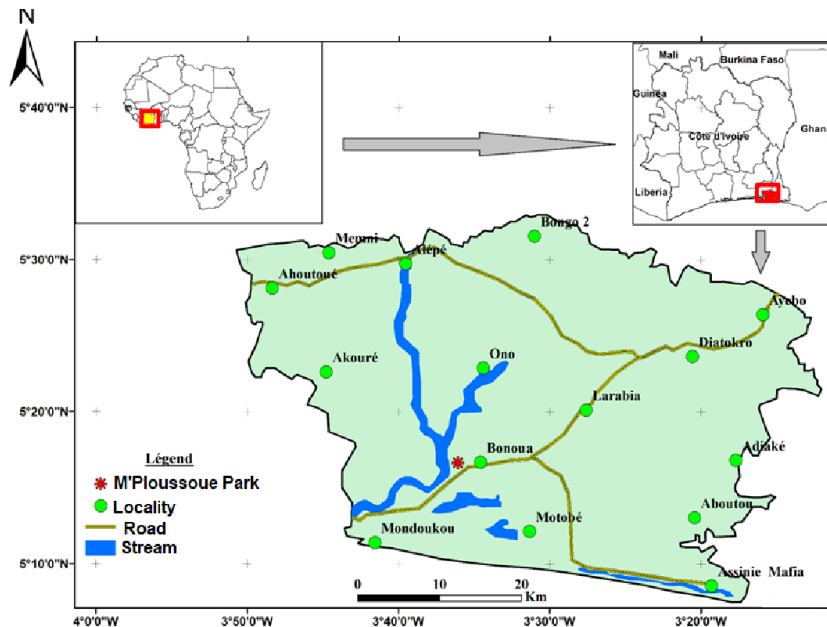


Fig.1: Localization of Study area

Soil samples

The soil samples were collected at 18 different points on the abandoned dumping site at 0-30 cm deep, according to random sampling technique. Soil samples were sieved to 2 mm to remove various types of wastes (paper, used batteries, electronic goods, wood, plastic paper, straws, buckets, tin cans, sacks, clothes, glass bottles, cotton wool, food wastes, leaves, fruit wastes, medicine bottles, foams, ashes, water sachet, card board and human excreta), then mixed and homogenized to obtain a composite sample. The composite sample were air-dried and brought to the laboratory for various analysis.

Another soil sample from other sector was also taken as soil control to compare the quality of soil from dumping site.

Laboratory analysis

Several analyses were performed to study the parameters that evaluate soil quality. The particles size was carried out by pipette of Robinson-Köln method and soil textural classes were carried out by using the textural triangle (Robert and Frederick, 1995). The Walkley and Black method and Kjeldahl method were used to determine respectively Organic Carbon and total nitrogen (N-total). Available P was

determined using Bray ascorbic acid method. Soil pH was determined in 1: 2.5 (w/v) (soil/water or potassium chloride solution) ratio using electrode pH-meter (Mathieu and Pieltain, 2003). Exchangeable cations (Ca^{+2} , Mg^{+2} , Na^{+} and K^{+}) and Cation exchange Capacity (CEC) were determined using Metson (1956) method. Heavy metals (Pb, Cd, Cr, As, Cu and Zn) were then analyzed by atomic absorption spectroscopy (ICP-OES) (Spectroblue). The analysis of the pH, Exchangeable cations, CEC and the contents in heavy metals were performed in the laboratory of Institute of Ecology and the Sciences of Environment of Paris (IESE), France. But the analysis of the granulometry, C, N, P available were realized in the laboratory of soils and plants in National Polytechnic Institute Félix Houphouët Boigny (INP-HB) of Yamoussoukro, Côte Ivoire.

Statistical Analysis

The data was subjected into statistics analysis using 7.1 statistcat software at 5% probability level. Significant differences between different parameters (particle size, chemical parameters, heavy metal content) under dumping soil and control soil were performed using Student–Newman–Keuls (SNK) test at $\alpha < 5\%$ probability level.

RESULTS

Soil Particle Size

Soil physical properties are presented in Table I. Sand is the dominant particle size fraction in both areas studied (dumping site soil and control soil, ranged 77% - 79%), followed by Clay (18% -21%), with silt been the lowest (1.6% -3%). They are not significant difference in the mean value of percentage of sand and clay in both areas (control and dumping sites). Silt content is significantly highest in control soil (3%) then in waste dumping site soil (1.6%) as presented in Table I.

Table I : Percentage particle size fraction (%) of the soil of dumping and control sites

Site	Particle Size (%)		
	Clay	Silt	Sand
Dump	21.3 ± 2 ^a	1.6 ± 0.3 ^b	77.1 ± 5 ^a
Control	18 ± 3 ^a	3 ± 1 ^a	79.2 ± 9 ^a

a, b, c values with the same letter indicate no significant difference between particle size of dumping site and control site (Student's t-test, $p < 0.01$)

Chemical parameters at control and wastes dumping sites

The chemical characterization of the two soils studied (dump and control sites) indicates that the control soil is moderately to strongly acidic with a water pH = 5.8 and a potassium chloride $\text{pH}_{\text{KCl}} = 4.5$ while the dumpsite soil is slightly acidic to neutral with a water pH = 6.9 and potassium chloride $\text{pH}_{\text{KCl}} = 6.1$ (Table II). The pH variation ($\Delta\text{pH} = \text{water pH} - \text{pH}_{\text{KCl}}$) of the dumpsite soil is $\Delta\text{pH} < 1$ showing high acidity potential.

In addition, both soils studied (dumpsite and control) have low levels of nitrogen (less than 1%), carbon (1-2%) and phosphorus (less than 2%). Organic matter content is highest in dumpsite soil (39000 mg.kg^{-1}) than in control soil (23400 mg.kg^{-1}) (Table II). However, a good rate of mineralization with a ratio C / N < 12 is observed in both sites. The calcium (4.39 cmol.kg^{-1}), magnesium (<1.1 cmol.kg^{-1}) and potassium (<0.25 cmol.kg^{-1}) contents are higher in dumpsite soil than in control which the contents are respectively 1.52 cmol.kg^{-1} ; 0.3 cmol.kg^{-1} and 0.05 cmol.kg^{-1} .

Table II: Chemical characteristics (pH, organic matter, available P, cations exchangeable, Cation exchange Capacity (CEC)) of dumpsite Soil and control soil (non polluted soil)

Site	pH		P _{available} (mgkg ⁻¹ dry soil)	Organic Matter (mgkg ⁻¹ dry soil)				Exchangeable cations (cmolk ⁻¹)				CEC
	pH _{water}	pH _{KCl}		C	N	MO	C/N	K ⁺	Na ⁺	Ca ⁺⁺	Mg ⁺⁺	
Dump	6.9±0.2	6.1±0.3	140±17	22600±90	2400±16	38872±155	9.41	0.25	0.21	4.39	1.04	7.92
Control	5.8±0.3	4.5±0.2	107	13600±50	1300±12	23400±86	10.5	0.05	0.18	1.52	0.3	8.72

Contents in heavy metals of dumpsite and control site soils

Metal content of both control and dumpsite soils is presented in Table III. The mean concentration of all heavy metal (Cr, Pb, Cd, Zn, Ni, As, Cu and Se) detected in dumpsite soil is significantly higher at p <0.001 than the mean concentration in control soil sample (Table III). The mean value of Pb, Cr and Ni are significantly at p <0.001 very higher in dumpsite soil with respectively 118 mg.kg⁻¹ soil dry, 130mg.kg⁻¹ soil dry and 119mg.kg⁻¹ soil dry than in

control site soil where the mean value of heavy metal is respectively 5.4 mg kg⁻¹ soil dry for Pb, 0.23 mg kg⁻¹ soil dry for Cr and 3.2 mg kg⁻¹ soil dry for Ni (Table III). For Cd (81 mg.kg⁻¹ soil dry), Zn (344 mg.kg⁻¹ soil dry), As (9 mg.kg⁻¹ soil dry), Cu (9.5 mg.kg⁻¹ soil dry) and Se (4.3 mg.kg⁻¹ soil dry), their contents are significantly high in the dumpsite soil than at control site soil where their values are below the limit of detection (Table III). In the dumpsite soil, the highest value of heavy metal is observed with Zn (344 mg.kg⁻¹ soil dry).

Table III : The mean concentration (mg.kg⁻¹ Soil dry) of some heavy metal in both studied areas

Sites	Heavy Metal (mgkg ⁻¹ dry soil)							
	Cr	Pb	Cd	Zn	As	Se	Ni	Cu
Dump	130.1±16 ^a	118±19 ^a	81±11	344±22	9.1±5	4.3±1	119±13 ^a	9.5±2
Control	0.23 ±0.01 ^b	5.4 ±0.2 ^b	nd	Nd	nd	nd	3.2 ±0.3 ^b	nd

Nd: not determined, values below the limit of detection. (a, b) values with the same letter indicate no significant difference between metal concentration detected on dumpsite and control site soils (Student's test, P < 0.001)

Comparison between of heavy metals contents of the Bonoua Dumpsite soil and recommended concentrations of metal in soil from different countries

Table IV shows that Cr, Pb, Cd, Zn and Ni concentrations detected in dumpsite soil exceeds

different standards recommended by World Health Organization and also those proposed in French and Canadian soils. But the content of As, Cu and Se are below of standards different recommended (Table IV).

Table IV: Comparison between observed and recommended concentrations of heavy metals in soil in different countries

Heavy metal (mgkg ⁻¹ dry soil)	Values observed in dumpsite soil	World Health Organization limit (WHO-limit)*	Canadian soil limit**	French soil limit***
Cr	130.1	70	64	70
Pb	118	100	70	100
Cd	81	0.35	3	1
Zn	344	300	200	300
Ni	119	50	50	50
As	9.1	40	12	-
Cu	9.5	100	100	100
Se	4.3	-		

*World Health Organization limit (WHO-limit) recommendation (WHO,1993)

** Canadian environmental quality criteria for contaminated sites (CCME) recommendation (CCME, 1999).

*** French Standards Association (AFNOR) limit recommendation (AFNOR, 1996).

DISCUSSION

Soil is a crucial component of rural and urban environments, and in both places land management is the key to soil quality. In the study area, the pH of the dumpsite soil is slightly acidic. The low acidity of dumpsite soil may be attributed to the age of waste dumping site which aging 10 years according to Praveena and Rao (2016) and El-Fadel *et al.*, (2002). This low acidity could favored the metal complexation (Kouamé *and al.*, 2006).

Moreover, the high organic matter content observed in open dumpsite soil than in control site soil could be attributed to the nature of various types of municipal solid wastes found in study area such as paper, used batteries, electronic goods, wood, plastic paper, straws, buckets, tin cans, sacks, clothes, glass bottles, cotton wool, food wastes, leaves, fruit wastes, medicine bottles, foams, ashes, water sachet, card board and human excreta. Other researchers attributed the high concentration of organic matter observed in the dumpsite soil to the presence of non-fermentable materials in the wastes which tend to resist to the decomposition and therefore, break down very slowly (Akpaki *and al.*, 2014; Ziraba *and al.*, 2016). The slow decomposition of wastes materials observed under dumpsite soil, due to the waste nature, could explain the lowest capacity of exchangeable cations observed in dumpsite soil as demonstrated by Praveena and Rao, (2016). Ours results were showed that nitrogen content was twice as high in dumpsite soil than control soil and phosphorus content was also higher in dumpsite soil than control soil. For Soheil *and al.*, (2012), the high nitrogen and phosphorus content recorded in dumpsite soil could be attributed to the nature and to high Soil Organic Matter (OM) content found in dumpsite soil. Because SOM is the major storehouse of many nutrients in soils including Nitrogen and phosphorus.

The continuous accumulation of municipal solid wastes of different sources such as electronic goods, electro plating waste, painting waste, used batteries could be at the origin of the heavy metal observed in the dumpsite soil, explaining the high levels in heavy metal in dumpsite soil. This result are in agreement with various studies conducted in landfills (Kouamé *and al.*, 2006; Suh *and al.*, 2004; Akpaki *and al.*, 2014) which attribute the high concentration of heavy metals in soils to the nature of solid waste.

The concentration of Cd (81 mgkg⁻¹), Cr (130 mgkg⁻¹), Zn (344 mgkg⁻¹), Pb (118 mgkg⁻¹) and Ni (119 mgkg⁻¹) in dumpsite soil are greater than limit values recommended for agricultural soil. This result stipulate that dumpsite soil is contaminated with those metals, which may constitute an environmental problem, if those metals migrates into the groundwater and plant.

The soil content of Cr (130 mgkg⁻¹) in the dumpsite soil studied is far above the permissible limits and is also higher than the data from Akouedo dumpsite soil (125 mgkg⁻¹) at Abidjan of Ivory Coast (Kouamé *and al.*, 2006) and also than the data from Al AIN (19.1 mgkg⁻¹) of Emirats Arabe Uni (Suh *et al.*, 2004). The Pb content (118 mg.kg⁻¹) in the dumpsite soil studied was relatively higher than the Pb content from Lome dumpsite (108 mgkg⁻¹) of Togo (Akpaki *and al.*, 2014) and lower than Pb content from Akouedo dumpsite (1500 mgkg⁻¹) at Abidjan (Kouamé *and al.*, 2006) and from Yamoussokro dumpsite (163.7 mgkg⁻¹) of Ivory Coast (Yobouet *and al.*, 2010). Similarly, the Zn soil content (344 mgkg⁻¹) in the dumpsite soil studied is higher above permissible limit for agricultural soils and lower than Zn content from Akouedo (1164 mgkg⁻¹) at Abidjan (Kouamé *and al.*, 2006) and Yamoussokro dumpsites (487 mgkg⁻¹) of Ivory Coast (Yobouet *and al.*, 2010) but is higher than Zn content from Al-AIN (117 mgkg⁻¹) of

Emirats Arabe Uni (Suh and *al.*, 2004). However Cd content (81 mgkg^{-1}) in the dumpsite soil studied was higher than Cd content from Akouedo (11 mgkg^{-1}) at Abidjan (Kouamé and *al.*, 2006), from Yamoussokro (4.65 mgkg^{-1}) dumpsites of Ivory Coast (Yobouet and *al.*, 2010) and from Lome (37.3 mgkg^{-1}) of Togo (Akpaki and *al.*, 2014).

Heavy metals present in the dumpsite soil studied could be serious environmental hazards from the point of view of polluting the soils (Chukwudi and *al.*, 2017). For Hargreaves *and al.*, (2008), this high organic matter content could favored the sorption of metal because soil organic matter (SOM) has a large sorption capacity towards metals (Quenea and *al.*, 2009; Yin and *al.*, 2002). This metal-SOM interaction could have various and complex consequences both on the solubility, mobility and bioavailability of metals. Furthermore, the low acidity of dumpsite soil pH could contributed metal bioavailability, toxicity and leaching capability into the surrounding areas (Chimuka and *al.*, 2005) and posed soil deterioration for agricultural.

CONCLUSION AND RECOMMENDATION

The analyze of soil samples collected from solid waste disposal site of M'Ploussou Park in Bonoua, indicate the high levels of heavy metal (Cr, Pb, Cd, Zn, N) which their contents exceeds the permissible limits, indicating the higher pollution potential. Municipal solid wastes dumped in M'ploussou Park of Bonoua contain important pollutant which can threaten the quality of soil. Moreover, this uncontrolled open-air dumpsite can threaten the ground-water and surface water resources. In this case, it appears important to proper methods of waste disposal have to be undertaken to ensure that it does not affect the environment around the area or cause health hazards to the people living there. Thus, to limit heavy metal migration in plants, groundwater and surface water resources, proper techniques phytoremediation must be performed at the site.

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