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Physical Characterization of the Superficial Layers of Akouedo Landfill, Ivory Coast and Assessment of Heavy Metals Pollution Risk of the Underlying Aquifer

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ABSTRACT

The present study aims to quantify heavy metals in the Akouedo landfill soil and evaluate the extent of contamination to better understand the risk of continental terminal groundwater contamination. The granulometric characteristics of six soil samples and three batches of auger samples at different depths up to 6 m showed that sand fraction was between 60.61 and 73.10 % with the average values between 63.91 and 67.19%. The fine particle content that reflects the rate of clay was between 26.90 and 39.39% with mean values between 32.81 and 36.09%. The chemical analyses showed that Akouedo landfill is rich in Zn (33.32-9440.00 ppm), Cr (55.60-4240.00), Cu (17.36-2800.00) and Pb (46.80-2580.00). The concentrations and the distribution of the different heavy metals in the auger samples vary with depth. The values were high in the surface layers and decreased in the deep layers. But chromium had higher mobility and could reach groundwater easily and to cause a contamination of this resource.

1. Introduction

Groundwater is the main source of drinking water for African people [1]. However, they are exposed to surface contamination since they are partly renewed by rainwater [2]. By infiltrating into the ground, rainwater carries with them solutes likely to contaminate groundwater. These water resources protection remains so a major concern for ensuring the populations health. In Ivory Coast, the district of Abidjan supplied with drinking water exclusively from the continental terminal aquifer, which accounts for 68% of national drinking water production [3]. The quality of this groundwater resources is subject to a growing threat of contamination due in part to the Akouedo landfill classified as an uncontrolled landfill [4]. This landfill which receives annually 550000 tonnes of solid wastes, two thirds of which household waste a third of industrial waste and sometimes dangerous today resembles a wild landfill [5]. These solid wastes may contain several heavy metals or metalloids which could poses severe environmental threat particularly affected groundwater resources and soil quality [6]. Dumpsites have been identified as one of the major environmental risk related to unsanitary landfilling of solid waste [7,8]. The vertical mobility can cause the contamination of the groundwater. In addition, the geological context primarily made up of sand and clay could offer a priori conditions favorable to the migration of the pollutants towards groundwater. Nevertheless, the quality of water from the upstream groundwater collecting fields was not yet reached by the pollutants of the landfill and was of good quality for the domestic needs [3]. However, several investigations indicated that the migration of heavy metals in the soil was very low during the first decades after deposition, compared to the accumulated amount [9,10]. So, the unsaturated zone can be considered as a source of nearly water pollution since heavy metal seep to this zone over a long period of time [11]. Therefore, continued attention to heavy metals from the Akouedo landfill leachate in the soil is always necessary. This study was initiated to provide a contribution to the assessment of the contamination of the continental terminal groundwater by the Akouedo landfill. It aims to assess the quality of the soil below the wastes of Akouedo landfill through the geotechnical and chemical characteristics of the soil.

2. Experimental Methods

2.1 Study Area

Akouedo landfill is located at the North-East part of Abidjan, between 395,800 and 397,600 m East longitude and between 591,400 and 592,200 m North latitude of UTM referential Zone 30 (Fig. 1). It extends on a 100 ha and the area was not prepared before the use for waste disposal. Urban solid residues were simply deposited on the land since 1965 [3]. No proper compaction of solid waste is carried out at the site and the underground drainage system, liner cover system and leachate collection system were found absent. Akouedo landfill receives 550 000 tonnes of waste per year [12]. The predominant geology in the area is the sedimentary formations made from up to bottom of clayey sands, medium sands and coarse sands resting on a granitic and schistous base [12].

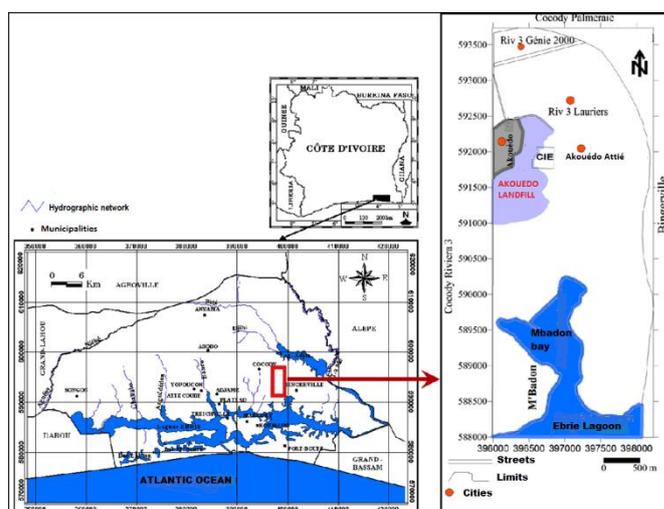


Fig. 1 Location of Akouedo landfill, Abidjan, Ivory Coast

2.2 Soil Sampling

Two types of samples were taken. These are six soil samples taken from the soil surface numbered S1 to S6 and three (T1 to T3) batches of auger samples at different depths up to 6 m (Fig. 2). The procedure consists in putting pressure on the auger by rotation in the direction of clockwise.

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Tool gradually sinking into the soil column and recovered sample is collected in labeled bags. Soil layers were determined at each change of soil color. Finally, 7 soil layers samples were collected for each site. A total of 21 samples of soil were collected for heavy metals and geotechnical analyzes. These geotechnical analyzes were granulometric analyzes and Atterberg Limits determination.

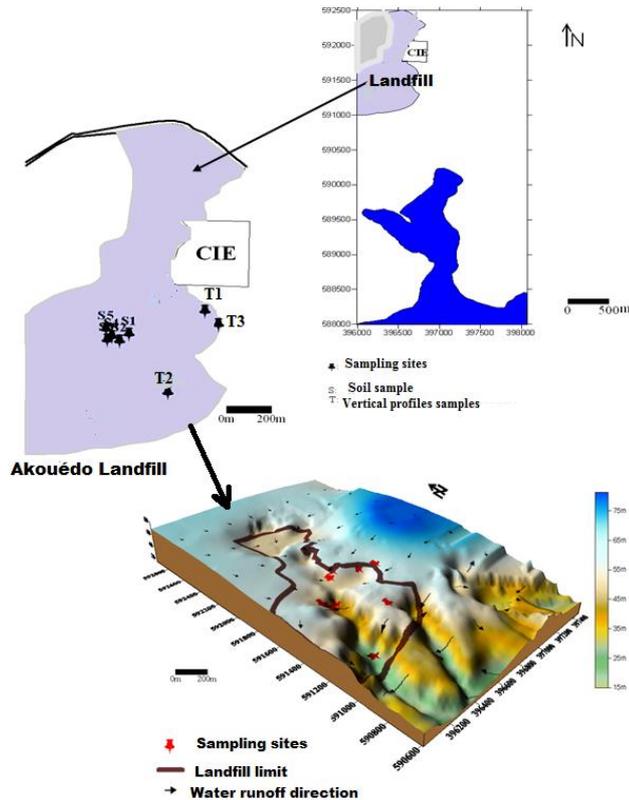


Fig. 2 Location of the soil sampling sites

2.3 Soil Samples Analysis

2.3.1 Granulometric Analyzes and Atterberg Limits Determination

The granulometric analysis consisted in splitting up a soil sample into groups of particles of close size using a column of 12 sieves with diameters ranging from 5 mm to 80 μm. The percentage of fine particle fraction of the different layers was obtained. In addition, when this fraction is more than 12% it is necessary to complete this analysis with the Atterberg limits. Atterberg limits determine the consistency of soil. The Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) of soils were determined. The liquid limit was determined by the Casagrande method and the plastic limit by the standard thread-rolling method. The plasticity index was determined by this calculation: $PI = LL - PL$.

2.3.2 Heavy Metals Analyses

The soil samples were digested with the mixture of HNO_3 and H_2O_2 . The solution obtained was filtered through a 0.45 μm cellulose membrane filter and diluted to 10 mL then stored at 4 °C before analysis. Concentration of in the digestion solution was determined by inductively couple plasma mass spectroscopy (ICP-MS).

3. Results and Discussion

3.1 Soil Characteristics

The granulometric characteristics of the different layers the soil samples are presented in Table 1. Sand fraction was between 60.61 and 73.10% with the average values between 63.91 and 67.19%. The fine particle content was between 26.90 and 39.39% with mean values between 32.81 and 36.09%. The results clearly show that the sand content was higher than fines content. However, the fine fractions were greater than 12%. It is necessary to determine Atterberg limits for these types of soils. Table 2 presents the values of Atterberg limits. The mean values of Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) were between 28.33 and 35.83%, between 13.83 and 16.83% and between 14.50 and 19.00% respectively. Atterberg limits obtained were less than 50%. These soils can be classified as a fine-grained soil (silty and clayey).

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Table 1 Sand content and fine particle content of the different layers

		T1	T2	T3
Sand (%)	Min	60.61	63.48	61.55
	Max	71.38	65.07	73.10
	Mean ± SD	64.64 ± 3.59	63.91 ± 0.69	67.19 ± 4.87
Fine particle (%)	Min	28.62	34.93	26.90
	Max	39.39	36.52	38.45
	Mean ± SD	35.36 ± 3.59	36.09 ± 0.69	32.81 ± 4.87

Table 2 Atterberg limits of auger samples

		T1	T2	T3
LL (%)	Min	24.00	32.00	23.00
	Max	38.00	39.00	39.00
	Mean ± SD	33.67 ± 5.01	35.83 ± 2.71	28.33 ± 6.50
PL (%)	Min	14.00	15.00	8.00
	Max	19.00	19.00	19.00
	Mean ± SD	16.00 ± 2.00	16.83 ± 1.72	13.83 ± 4.07
PI (%)	Min	10.00	17.00	8.00
	Max	22.00	20.00	20.00
	Mean ± SD	17.67 ± 4.41	19.00 ± 1.10	14.50 ± 4.23

3.2 Heavy Metals Concentrations and Distribution in Soil

The minimum, maximum, and mean values of heavy metals of soils are summarized in Table 3. All of the investigated metals had a wide range of concentration values, depending on location and sampling station. The mean values of Zn, Cr, Cu and Hg were 1981.29 ± 3678.52 ppm, 856.13 ± 1664.32 ppm, 614.23 ± 1110.37 ppm and 4.56 ± 1.09 ppm respectively. The concentrations of Pb and Cu were at the similar level.

Table 3 Heavy metals concentrations of soil samples

	Hg	Cr	Cu	Pb	Zn
Min	2.62	55.60	17.36	46.80	33.32
Max	5.97	4240.00	2800.00	2580.00	9440.00
Mean	4.56	856.13	614.23	614.00	1981.29
SD	1.09	1664.32	1110.37	1006.27	3678.52

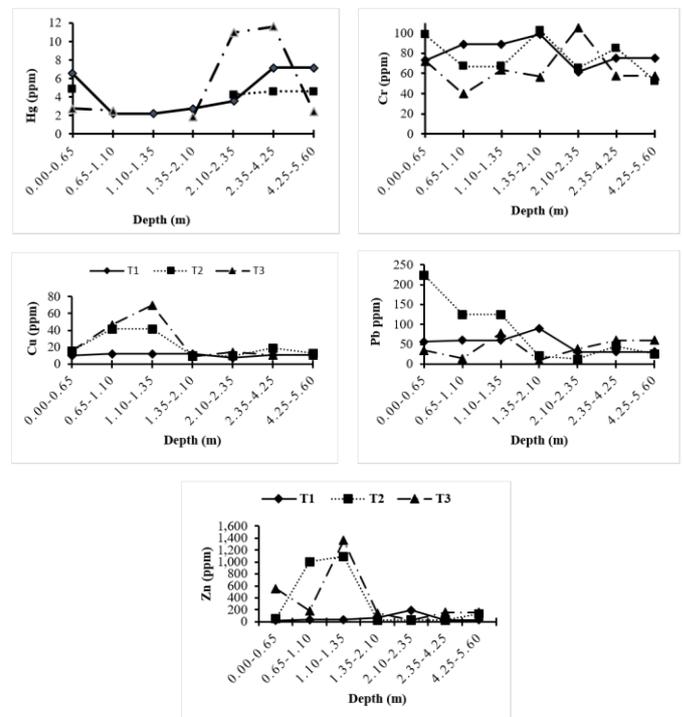


Fig. 3 Heavy metal distribution in soil

Fig. 3 shows the concentration and distribution of the different heavy metals in the auger samples. Generally, the concentration of these heavy metals varies with depth. The highest concentrations of Hg were obtained in depth beyond 2 m of depth. In contrary, the concentrations of Pb, Zn and Cu were high in the surface layers and decreased in the deep layers. The values of Cr concentrations in depth and those obtained in the surface layers were similar. The abundance order of heavy metal contents auger samples was: $Zn > Pb > Cu > Cr > Hg$.

This research explores the risk of soil contamination by heavy metals from Akouedo landfill. The granulometric characteristics of the soil samples showed that sand fraction was higher than the fine particle content. However, the fine fractions were also greater than 12%. The mean values were between 32.81 and 36.09%.

This fraction reflects the rate of fine particles such as clay in the soil, which can influence the mobility of heavy metals. Moreover, the values of Plasticity Index were between 14.50 and 19.00%. These values confirm an excess of clay or colloids in the soil. We can conclude that the soils of Akouedo landfill are clayey sand. These results are similar to those of Kouame et al. [3]. These authors showed that Akouedo's geological profile consisted of clayey sand, medium sands, coarse sands, and granito-gneiss base.

The concentration of heavy metals in surface soils showed a wide range of concentration values, depending on location and sampling station. High concentrations coupled with wide range of values suggests anthropogenic sources for these elements. The concentrations were found to follow the order: Zn > Cr > Cu > Pb > Hg. The concentrations and the distribution of the different heavy metals in the auger samples vary with depth. The values were high in the surface layers and decreased in the deep layers except Hg which the highest values were obtained in depth beyond 2 m of depth.

The variation of heavy metals distribution in the auger samples may be attributable to the abundance of the clay and organic matter [13]. Generally, the decreasing heavy metal content trend with depth can be attributed to the recycling of essential nutrients to the surface horizons. Organic matter content was concentrated in the surface horizons [14]. Organic matter of soil is a barrier for these metals. About Cr concentrations, the values in depth and those obtained in the surface layers were similar. These results showed that there was a high mobility of Cr to depth. According to few research groups [15-17], adsorption in the soil allows the retention of the majority of metals on the organic matter very abundant in the surface layers and on the clayed layers. But chromium is not much adsorbed and migrates more towards the deep layers. Cr is thus able to reach the groundwater easily and to cause a contamination of this one.

4. Conclusion

This study showed that geological formations provide favorable conditions for the migration of some pollutants. The presence of organic matter and clay had a direct consequence on the soil's ability to retain pollutants. Zinc, lead, copper and mercury are strongly adsorbed on layers rich in organic matter and clay. Chromium had higher mobility and could reach groundwater and contaminate it.

References

- [1] J. Gronwall, S. Oduro-Kwarteng, Groundwater as a strategic resource for improved resilience: a case study from peri-urban Accra, *Environ. Earth Sci.* 77(6) (2018) 1-13.
- [2] N. Soro, T. Lasm, B.H. Kouadio, G. Soro, K.E. Ahoussi, Variability of the rainfall pattern of southern Côte d'Ivoire and its impact on the feeding of the Abidjan aquifer, *Sud. Sci. Technol.* 14 (2006) 30-40.
- [3] I.K. Kouame, D.L. Gone, I. Savane, E.A. Kouassi, K. Koffi, B.T.A. Goula, M. Diallo, Relative mobility of heavy metals resulting from Akouédo landfill and assessment of Continental Terminal groundwater contamination risk (Abidjan-Côte d'Ivoire), *Afrique Sci.* 02 (2006) 39-56.
- [4] O.A. Adjiri, C.K. Mafou, P.K. Konan, Impact of Akouedo landfill (Abidjan - Côte d'Ivoire) on the populations: socio-economic and environmental study, *Int. Jour. Innov. Appl. Stud.* 13(4) (2015) 979-989.
- [5] G. Kouadio, B. Dongui, A. Trokouré, Determination of chemical pollution of waters in the Akouedo landfill area (Abidjan - Côte d'Ivoire), *Ivorian Jour. Sci. Tech.* 1 (2000) 34-41.
- [6] V. Partha, N.N. Murthya, P.R. Saxena, Assessment of heavy metal contamination in soil around hazardous waste disposal sites in Hyderabad city (India): natural and anthropogenic implications, *J. Environ. Res. Manage.* 2 (2011) 027-034.
- [7] S. Mor, K. Ravindra, R.P. Dahiya, A. Chandra, Leachate characterization and assessment of ground water pollution near municipal solid waste landfill site, *Environ. Monit. Assess.* 118 (2006) 435-456.
- [8] R. Maheshwari, S. Gupta, K. Das Impact of landfill waste on health: An overview, *Jour. Environ. Sci., Toxicol. Food Tech.* 1 (2015) 17-23.
- [9] M. Majone, M.P. Papuini, E. Rolle, Influence of metal speciation in landfill leachates on kaolinite sorption, *Water Res.* 32, 3 (1998) 882-890.
- [10] S. Hellweg, T.B. Hofstetter, K. Hungerbühler, Time-dependent life-cycle assessment of emission from slay landfills with the help of scenario analysis: the example of Cd and Cu, *Jour. Cleaner Prod.* 13(3) (2005) 301-320.
- [11] S. Hellweg, U. Fischer, T.B. Hofstetter, K. Hungerbühler, Site dependent fate assessment in LCA: transport of heavy metal in soil, *Jour. Cleaner Prod.* 13(3) (2005) 341-361.
- [12] I.K. Kouame, B. Dibi, K. Koffi, I. Savane, I. Sandu, Statistical approach of assessing horizontal mobility of heavy metals in the soil of Akouedo landfill nearby Ebrié lagoon (Abidjan-Côte d'Ivoire), *Int. Jour. Conser. Sci.* 1(3) (2010) 149-160.
- [13] G. Louhar, R. Yadav, R.S. Malik, S. Yadav, Depth wise distribution of heavy metals in different soil series of Northwestern India, *Int. J. Curr. Microbiol. App. Sci.* 8 (2019) 2817-2826.
- [14] B.D. Lee, B.J. Carter, N.T. Basta, B. Weaver, Factors influencing heavy metal distribution in six Oklahoma benchmark Soils, *Soil Sci. Soc. Am. J.* 61 (1997) 218-223.
- [15] T. Sherene, Mobility and transport of heavy metals in polluted soil environment, *Biol. Forum - Int. Jour.* 2 (2010) 112-121.
- [16] I.K. Kouamé, L.K. Kouassi, B. Dibi, K.M. Adou, I.D. Rascanu, et al., Potential groundwater pollution risks by heavy metals from agricultural soil in Songon Area (Abidjan, Côte d'Ivoire), *Jour. Environ. Protec.* 4 (2013) 1441-1448.
- [17] J.J. Gonzalez-Costa, M.J. Reigosa, J.M. Matias, E. Fernandez-Covelo, Analysis of the importance of oxides and clays in Cd, Cr, Cu, Ni, Pb and Zn adsorption and retention with regression trees, *PLoS ONE* 12 (2017) 0168523:1-25.