Lixiviation of Open-Coast Dumping Site and Pollution of Water and Soils of Edéa Industrial Zone (Littoral-Cameroon)

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Abstract: The nexus between water, food and energy is one of the most fundamental relationships and challenges for society. Indeed, seepage of wastes stored into dumping sites of Edea township, favor their lixiviation. Soluble components of matter are slowly dissolves, drained by meteoric water and flowed into tail bay vicinity. Knowledge of trace and toxic metal concentrations in the biotic matrices is important for assessing the effects of pollutants and the risk of exposure. In this study, Al, Mn, Cd, Cr, Cu, Pb and Zn were quantified respectively in 33 samples of soil and water, using ICP-MS (Inductively Coupled Plasma Mass Spectrometry), Pb were found between 1.38-88.28 mg/L. Higher concentrations of Al were found in Alucam industrial wastes (315,502.33 mg/kg), and in Hysacam domestic wastes (54,126.93 mg/kg). Concentrations of Cd (1.955 mg/kg), Pb (469.00 mg/kg) and Zn (853.00 mg/kg) are higher in domestic wastes. The ones of Mn (696.96 mg/kg) and Cu (1,320.10 mg/kg) are higher in industrial wastes. Higher concentrations of Pb and Cu let assume that it is a risk of poisoning relative to these elements around this area. These findings illustrate that lixiviation of dumping wastes has great influence on water and soils pollutions of the study ecosystem.

Key words: Dumping site, lixiviation, metallic trace elements, pollution, chemical intoxications.

1. Introduction

MTE (metallic trace elements) are conventionally defined as metals whose mean natural concentration in the upper continental crust is less than 1,000 mg/kg. MTE are indispensable to the functioning of biological process; they are oligo-elements (Cu and Zn). Nevertheless, some as Cd, Hg, Pb, Cr, Ni and Se are not indispensables and can be harmful for different forms of life when their concentrations are higher [1]. Rock's MTE are generally fixed in acid and silicate or sulfide and carbonate forms. Oxides released by erosion are carried in soils and sediment, while sulfides (more alterable) are attacked chemically and soluble elements are trapped by clays [2]. Their

distribution in soils and sediments is evidence of physico-chemical and biological processes affecting aquatic eco-systems [3]. Located in the Cameroon littoral zone, Edea is equally concerned about eco-systematic problems related to water, as well as erosion and sediments carriage. Agricultural overproduction, irrigation and water collection for domestic and industrial use, urbanization, development of infrastructures are factors that affect significantly its ecosystem. Lixiviation of the two open-cast dumping sites in the Edea I urban council is certainly one of the major damage of the locality. Indeed soluble elements (potentially toxic) extracted by percolation expose the biotic species of pear by aquatic eco-systems to risks of contamination and pollution. Administrative history of Edea town began in 1890 with the creation of the first office by Germans. For more than half a century, numerous

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industries have fit in amongst which: the Cameroon Aluminium Company, the Cameroon Aluminium Transformation Company, the paper pulp industry (Cellulose of Cameroon) and Edea & Songloulou hydro-electric power dams. The implantation of these industries has generated an important migratory flow in one hand and a significant production of diverse wastes on the other hand. They are collected and stored by the hygiene and sanitation factory (Health and Salubrity of Cameroon) in an open-cast dumping site. Their exposure to climate hazards increases the disturbance and pollution risks in this environmental eco-system. Indeed, during the last decades, these rubbish dumps have noted an important supply of various litter rich in metallic trace elements. The origin of MTE supply is not well-known as well as their mobilization and migration process. On the other hand, it is known that anthropogenic activities increase with demographic explosion and contribute to modify the spatial distribution of chemical elements and MTE [2]. Agriculture and industrial activities are classified among the most important anthropogenic sources relative to supply and spatial redistribution of MTE [4]. As a matter of fact, numerous MTE like Cd, Cr, Mo, Pb, U, V, Zn, As, Hg, Cu, Mn and Zn are widely found in miscellaneous metallic forms in wastes and residues [5, 6].

A better understanding of MTE mobilization, transportation, sedimentation and bioaccumulation process in separate biotic species of the study zone is essential. Indeed, heavy metals contamination of different trophic levels has become crucial during the last decade, due to their potential accumulation in the different bio-systems through effluent, air, soil and sediments [7]. Numerous topics relatives to wet land soils and water have been conducted, but the environmental aspect has received very little attention. The aim of the present work is to settle the concentration of undesirable and toxic MTE of different biotic species and to study the pollution index, for an efficient management of environmental

problems in the Edea I council.

2. Materials and Methods

2.1 Environmental Setting

Edea is located in the coastal plain of the Cameroon littoral zone, between latitude 03°45' N to 03°50' N, and longitude 10°05' E to 10°10' E (Fig. 1). The study area is located at 03°47'58" N-10°08'30" E. The climate is the Guinean type [8]. The total annual precipitation ranges between 2,000 mm and 4,000 mm for the period ranging between 1972 and 2009. The mean annual temperature oscillates between 26 °C and 27 °C. The vegetation is a dense humid evergreen biafran forest of low and mid altitude with species as Caesalpiniaceous [9]. This primary vegetation is presently degraded by human and urban pressure. The main soil types are yellow ferralitic soils [10, 11]. Edea locality belongs to the coastal plain composed of a succession of low plateaus with variable altitude and coastal lowlands [12, 13]. The drainage network is parallel to rectangular trend, denser in the north-east side than the west side. The main geological formations are acid metamorphic rocks presenting three features: gneiss, garnet mica-schist and quartzite. The gneissic rocks are composed of biotite gneiss, biotite and amphibole gneiss, biotite-garnet-pyroxene gneiss. This gneiss constitutes the most abundant feature.

2.2 Dumping Sites Presentations

Elog Belle rubbish dump is located between north latitudes 03°47'39" N to 03°48'39" N and east meridians 10°06'00" E to 10°07'01" E. Materials observed in a deep winding-shaft of 4.65 m are characterized from bottom to top of: a lower soft clayey unit, an upper soft clayey unit, a clayey layer with wrecks, a darks brown layer and a reddish black layer (Fig. 2).

Alucam rubbish dump is situated behind the aluminium factory, between north latitudes 03°47'00" N to 03°48'05" N and east meridians 10°07'25" E to 10°08'58" E. It is an embankment of 2.5 ha, which

Fig. 1 Location map of Edéa study area.

is a peneplain relief, directly connected to the Sanaga. Materials observed in a deep winding-shaft of 5.10 m are characterized from bottom to top of: a dark brown layer, a whitish grey layer, an olive grey layer and a dark grey layer (Fig. 3).

2.3 Sampling and Experimentation Methodology

Soils and water samples were collected for this study. Soils samples were collected on vertical cross-section using a hammer. They were tied in tissue paper and conserved in a cooler in view of laboratory analyses (bulk density, particle density and mineralogy). Disturbed and undisturbed samples were collected in the same vertical profile, but at different depths.

Chemical determination of MTE was done in Geosciences Laboratories (Sudbury Canada). Soils

samples were crushed, and then pulverized into a ball composed of 99.8% alumina. Concentrations of major elements (Al, Mn) were determined after calcinations, by X-ray fluorescence. Powder obtain after this process were mixed with lithium tetracarbonate before analysis by Rigaku RIX-3000 Spectrometer mark. International standards (BIR-1-0949, SDU-1-0295 and SDU-1-0296) as well as internal laboratory standards were used. ICP-MS (Inductively Coupled Plasma Mass Spectrometry) analyses were conducted to settle the concentration of lithophile trace elements. Samples were diluted into HCl acid/HClO₄ mixture at 120 °C in Teflon cup for one week, then in HNO₃ acid and finally dried. Fraction of share was dissolved in a mixture of three acids (HCl + HClO₄ + HF) at 100 °C. Samples were then ready to be analyzed using ICP-MS (Perkin Elmer Elan 900 mark). For the IM

Fig. 2 Vertical cross-section of Edea-Elog Belle dumping site materials.

Fig. 3 Vertical cross-section of Edea-Alucam dumping site materials.

100 analysis, three reference certified samples were measured, their mean were used to determine the reliability of the instrument on the one hand, and to compare values obtained for other samples on the hand. The zero nominal concentration is equal to the measure responses of blank. Standard solutions were measured between each series of 30 samples with a test after passage of 10 samples. Data were reported for a wide bland of transition elements.

Water pattern was sampled both in Elog Belle (Health and Salubrity of Cameroon) and Alucam dumping sites. Four sampling points were determined: three in Elog Belle and one in Alucam (Fig. 1). Sampling points coded EDH and EDA represent respectively the exit point of a lake (which empties in the principal collector), and the exit point of industrial waste waters. Water samples were collected in pre-sterilized PVC bottles. Each bottle was first rinsed three times with the water to be analyzed. After setting apart, PVC bottles were tightly closed, labeled and transported to the International IITA (Institute for Tropical Agriculture) Laboratory for analysis. Mg, Zn, Cu and Mn were analyzed by flame atomic absorption spectrometry while Al concentration was determined by colorimetry. Cd, Pb and Cr concentrations were determined by spectrometry DR/2010 using

kits/reagents. Colors were determined by the Munsell colour charts in the laboratory of Engineering Geology and Alterology of the Earth Science Department (University of Yaoundé I).

3. Results and Discussion

3.1 Results

3.1.1 Concentrations of Metallic Trace Element in Soils

Natural soils (control samples) of Edea locality show very high aluminium contents. For about 90.90% of samples, Cd concentrations are below the detection limits. The maximum cadmium contents recurred is equal to 0.06 ppm. Mn contents are below detection limits in 27.27% of samples. Nevertheless, all those concentrations are enclosed in the range of 77.44 ppm to 464.64 ppm, and are in conformity with norms prescribed by WHO (World Health Organization) as well as those of Cr, Cu, Pb and Zn (Table 1).

Elog Belle discharge soil shows MTE concentrations (except Al) that are in conformity with the norms of the WHO. However, the concentrations of Cu and Pb are above norms prescribed by WHO in 23.23% of the samples (Table 2). The abnormal

Table 1 Concentrations of metallic trace elements, depth, pH and mineralogy of natural soils of Edea (control).

WHO norms (mg/kg)		Part of the vertical cross section										
		Rock	Rough saprolite		Fine saprolite		Nodular system				Light clayey sytem (superficial)	
		Gneiss	Base	Top	Base	Top	Base		Top		Base	Top
							Nodules	Matrix	Nodules	Matrix		
Code		EDN ₀	EDN ₁	EDN ₂	EDN ₃	EDN ₄	EDN _{5n}	EDN _{5m}	EDN _{6n}	EDN _{6m}	EDN ₇	EDN ₈
Depth (m)	-	-	6.05	5.65	5.21	4.30	3.52	3.52	2.80	2.80	1.14	0.52
pH	-	-	5.50	5.65	5.44	5.75	6.29	5.60	5.54	4.72	4.82	5.52
Mineralogy		Q, A, CPx, M	Q, K, M	Q, K, M	Q, K, M	Q, K, M, He	Q, K, M, He, Gi	Q, K, M, He, Gi	Q, K, M, He, Go	Q, K, M	Q, K, Go	Q, K
Al	10-120	82,857.06	100,529.00	96,560.75	95,343.82	87,036.95	83,809.44	101,798.84	73,333.26	99,364.98	82,275.05	60,793.59
Mn	200-100,000	464.64	0.00	0.00	0.00	77.44	154.88	154.88	232.32	77.44	77.44	77.44
Cd	0.01-2	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cr	5-1,500	314.00	400.00	347.00	346.00	357.00	759.00	476.00	957.00	328.00	382.00	311.00
Cu	2-250	20.40	22.20	49.00	44.50	44.50	65.40	52.60	64.10	43.90	31.20	23.00
Pb	2-300	8.80	7.80	9.60	15.40	23.70	39.40	22.70	54.00	15.40	10.50	10.10
Zn	1-900	47.00	16.00	16.00	20.00	39.00	6,200	42.00	60.00	40.00	30.00	29.00

Table 2 pH and MTE concentrations of domestic wastes from Elog Belle (Hygiène et Salubrité du Cameroun).

WHO norms (mg/kg)	Part of the vertical cross section									
	Grey clayey sandy level	dark Grey clayey sandy level	Brown level	Yellow brown level	Brown level	Grey level	Clayey sandy level with debris	Brown level	dark Dark reddish level	
Code	EDH ₁	EDH ₂	EDH ₃	EDH ₄	EDH ₅	EDH ₆	EDH ₇	EDH ₈	EDH ₉	
Depth (m)										
pH		7.50	6.18	6.59	6.46	7.41	6.42	7.43	7.63	7.68
Al 10-120	52,751.27	46,719.53	46,613.71	54,126.93	47,936.46	49,894.13	47,142.81	45,079.32	39,947.05	
Mn 200-100,000	464.64	387.20	542.08	309.76	309.76	232.32	232.32	232.32	232.32	
Cd 0.01-2	1.96	0.96	1.18	0.78	0.18	0.08	0.36	0.29	0.17	
Cr 5-1,500	532.00	395.00	507.00	380.00	397.00	333.00	630.00	314.00	511.00	
Cu 2-250	335.30	99.30	148.40	122.00	1,320.10	29.10	45.40	118.40	82.40	
Pb 2-300	469.00	223.20	384.80	198.10	185.30	55.20	97.80	111.90	55.40	
Zn 1-900	672.00	853.00	589.00	389.00	204.00	110.00	260.00	270.00	274.00	

concentrations of Cu and Pb are respectively those of samples EDH₅ (1,320.10 mg/kg) and EDH₁ (335.30 mg/kg). Those of Pb are concern samples EDH₁ (469.00 mg/kg) and EDH₃ (384.80 mg/kg). However, Pb concentrations are quite high with respect to the norms (2-300 ppm). Only three samples, EDH₆ (55.20 mg/kg) < EDH₉ (55.40 mg/kg) < EDH₇ (97.80 mg/kg), show concentrations below 100 ppm. Mn concentrations are included between the normal intervals 200-100,000 mg/kg and ranged between 200 mg/kg and 600 mg/kg. two samples (EDH₃: 542.08 mg/kg and EDH₁: 464 mg/kg), out of nine, about 22.22% of samples show Mn concentration greater than 400 ppm. Three samples (EDH₂: 387.20 mg/kg, EDH₄ = EDH₅: 309.76 mg/kg) out of nine show concentrations ranges of 300-400 ppm. EDH₆, EDH₇, EDN₈ and EDH₉ samples show concentrations equal to 232.32 ppm. Cd concentrations are in conformity with WHO standard (0.01-2.00 mg/kg). Two samples (EDH₁: 1.955 mg/kg, and EDH₃: 1,178 mg/kg) go out of above 1 ppm. Cr contents are in the normal range of WHO (5-1,500 mg) and vary between 300 mg/kg to 650 mg/kg. The decreasing order of concentrations per sample is as follows: EDH₇: 630 mg/kg > EDH₁: 532 mg/kg > EDH₉: 511 mg/kg > EDH₃: 507 mg/kg > EDH₅: 397 mg/kg > EDH₂: 395 mg/kg > EDH₄: 380 mg/kg > EDN₆: 333 mg/kg > EDH₈: 314 mg/kg. Contents of samples EDH₁ (335.3 mg/kg) and EDH₅ (1,302.1 mg/kg) are above the WHO norm for Cu

(2-250 mg/kg). Other samples show concentration values which are in conformity with WHO norms and vary between 29.1 mg/kg and 148.4 mg/kg. EDH₁ (469.0 mg/kg) and EDH₃ (384.8 mg/kg) show Pb concentration that are higher than the WHO norms (2-300 mg/kg) while the other samples are in the normal range. The concentrations of Zn are all included in the range of 1-900 mg/kg recommended by the WHO. Sample EDH₂ (853 mg/kg) shows the highest concentration while EDH₆ shows the lowest one.

Soils samples obtained from Alucam industrial dumping site (Table 3), just like those of the control soils from Edea and Elog Belle dumping site, show very high aluminium concentrations compared to norms (10-120 mg/kg) prescribed by the WHO. Indeed, Al concentrations fluctuate between 25,132.25 mg/kg and 213,809.31 mg/kg, and testify a very high concentration of aluminous ions. Mn concentrations are for most cases below the minimum level (200 mg/kg) recommended by the WHO. Only the concentrations of EDA₁, EDA₆ and EDA₇ (696.56 mg/kg, 387.20 mg/kg and 232.32 mg/kg) respectively are higher than the minimum recommended value. The concentrations of the other samples range from 0.01 mg/kg to 2.00 mg/kg. Cr concentration varies between 80 mg/kg and 600 mg/kg, in conformity with the norms (5-1,500 mg) (Table 3), As for Cu, only EDA₂ (376.7 mg/kg) has a higher value than the

Table 3 MTE concentrations and pH of industrial wastes from Alucam.

WHO norms (mg/kg)	Part of the vertical cross section								
	Grey clayey sandy level	dark Grey clayey sandy level	Brown level	Yellow-brown level	Brown level	Grey level	Clayey sandy level with debris	Dark brown level	Dark reddish level
Code	EDA ₀	EDA ₁	EDA ₂	EDA ₃	EDA ₄	EDA ₅	EDA ₆	EDA ₇	EDA ₈
Depth (m)									
pH	-	7.45	8.13	8.00	7.68	7.88	9.02	7.96	8.13
Al 10-120	> 315,502.33	103,121.59	25,132.25	179,946.91	213,809.31	250,105.57	158,730.00	172,010.41	142,116.26
Mn 200-100,000	77.44	696.96	154.88	77.44	154.88	77.44	232.32	387.20	154.88
Cd 0.01-2	< 0.01	0.32	0.05	0.20	0.06	0.17	0.15	0.15	0.27
Cr 5-1,500	590.00	239.00	197.00	121.00	84.00	118.00	124.00	351.00	97.00
Cu 2-250	24.40	40.70	376.70	40.00	12.30	47.70	19.50	57.30	48.00
Pb 2-300	59.70	102.90	31.80	28.90	10.80	22.40	74.10	71.90	27.20
Zn 1-900	31.00	132.00	93.00	71.00	17.00	34.00	123.00	120.00	47.00

Table 4 Undesirable elements and pollution indicator in the nearby water of dumping sites.

	EDH	EDH-Milieu	EDH-rail	EDA	WHO Norms
Al (mg/L)	-	-	-	19.092	≤ 0.3 mg/L
Mn (mg/L)	0.00	0.00	0.00	0.00	≤ 0.1 mg/L
Cd (µg/L)	0.06	0.03	0.03	0.06	≤ 0.1 mg/L
Cr (mg/L)	0.09	0.06	0.03	0.17	≤ 0.5 mg/L
Cu (mg/L)	0.14	0.02	0.01	0.03	≤ 0.5 mg/L
Pb (µg/L)	2.91	12.96	1.38	88.28	≤ 50 µg/L
Zn (mg/L)	0.33	0.00	0.00	0.00	≤ 2 mg/L

WHO norm (2-300 mg/kg). Cu concentrations of other samples are in conformity with the norm (2-300 mg). Likewise, all soil samples of the Alucam dumping site show Zn concentration that range from 15 mg/kg to 135 mg/kg, in conformity with WHO norm (1-900 mg/kg).

3.1.2 Concentrations of Metallic Trace Elements in Water Surrounding Dumping Sites

Concentration of Al in the water samples from the Alucam dumping site (19.09 mg/L) is 64 times higher than the norm recommended by the WHO (≤ 0.3 mg/L) in surface waters. Mn contents in the samples are zero. Maximum cadmium concentrations (0.06 mg/L) are far below the norm (< 0.1 mg/L). Maximum contents of Cr (0.17 mg/L) and Cu (≤ 0.14 mg/L) are also very low compared to the WHO norms. Only the maximum concentration of Pb (88.28 mg/L) is higher than the WHO norm (≤ 50

µg/L) for surface water. Zn was found only in water samples from the Elog Belle dumping site. Its concentration (0.33 mg/L) is widely inferior to the WHO normal value (≤ 2 mg/L). Pb maximum concentration of water samples from Alucam (EDA: 88.28 µg/L) is 38 units higher than the norm (≤ 50 µg/L). Concentrations of EDH (1.38 µg/L), EDH (2.91 µg/L) and EDHm (12.96 µg/L) are in conformity with the norm (Table 4).

3.2 Discussions

Contrary to chemical organic compounds, metals are neither created nor destroyed by biological or chemical processes. It is well known that metals such as chromium, copper, iron, manganese, selenium and zinc are essential minerals in health maintenance since they play a very important role in homeostasis [2]. Consequently, a deficiency in these essential minerals

can be detrimental to health. An exposure of high concentrations of some toxic metals such as arsenic, cadmium, lead and mercury can be quite dangerous to health [14].

The reference soil profile located at Edea gives a clue on the potential contamination of soils at discharge plants. The natural soils or control samples coded EDN are acidic [15] when compared to those at the Elog Belle (Health and Salubrity of Cameroon) discharge coded EDH and those of Alucam (Aluminium of Cameroon) discharge coded EDA, which are slightly acidic and basic, respectively. The pH of the studied soils and sewage does not show any significant correlation with trace element content. This is in accord with the observations on the soils of Cameroon. Acidic pH can lead to aluminium toxicity and could be a limiting factor to the growth of plants. The aluminium concentrations in the studied profiles are higher compared to the maximum required for this element according to standards. The high aluminium concentration is due to the lixiviation of alkaline and earthy-alkaline elements, leading to soil acidity and the dissolution of neoformed minerals which liberate Al^{3+} ions. In natural pits, Mn concentrations are high in the rock and surface horizons. They instead increase with depth in the Elog Belle sewage and affirm the mobilization and accumulation of manganese ions towards the lower horizons and probably to the water table as well as surface waters. The zig zag (saw teeth) evolution of Mn concentrations in the soil at the Alucam sewage plant (EDA) does not permit the global determination of the mobilization and lixiviation processes going on at these discharge plant. Concentrations of cadmium increase with depth just like that of manganese. The pollution limit is rapidly reached (at the base of the sewage) attesting lixiviation, rapid migration and a high accumulation of cadmium ions in the layers underneath. This accumulation is higher than in other pits (EDA). Concentrations are equally high at the summit than at the base. Chromium

concentrations at the reference site (EDN) are in accordance with standards as noticed in the samples collected at the dumping sites (EDA and EDH). Their fluctuation which is of low significance does not reveal any danger to human health. High concentrations of Cu recorded in the studied dumping sewage plants are slightly higher according to standards attesting to pollution by this element. The decomposition and mineralization of organic matter are propitious to the high concentration of Cu in this ecosystem. Indeed, the composting and the spreading of mud around purifying stations are the main sources of Cu in the different environmental ecosystem. Zn concentrations change slightly in the reference soil sample. Two concentration peaks occur in samples originating from deeper levels of the Alucam dumping site (EDA), testifying to mobilization and average accumulation at depth. High concentration occurring in the Elog Belle dumping site (EDH) testifies a rapid migration and serious accumulation at depth. Zn and Pb show a similar trend certainly because of the affinity of the two elements. On the other hand, Zn concentration in samples collected at EDH sewage are similar to that of Mn thus suggesting an association between these elements. As a matter of fact, the highest proportion of Zn in soils and sediments were associated to Fe and Mn oxides [16]. Metallic trace elements concentrations in soils and clay sediments are related to the presence of Fe or Mn oxides whose "trapping" role ensures the accumulation of metallic elements. This is the same for heavy metals which are absorbed and immobilized by clay minerals [17]. This conjecture is reinforced by macroscopic observations which reveal that the studied samples/materials of Edea natural soils coded EDN and soils of dumping sites (EDH and EDA) are mostly clayey. Pb concentrations in samples from natural pits are low at depth and high at mid-depth. They are contrasting with the concentrations of samples obtained in EDA and EDH pits, whose values are also higher at the

surface than at depth for the first, low at the surface and high at depth for the second. These values which are relatively high according to standards show Pb pollution. As a matter of fact soils of dumping sites play a very important role in the immobilization of this element. It accumulates progressively and indefinitely from the upper horizons towards the lower ones. The accumulated metals, depending on their availability, are susceptible of being transferred to plants, then to animals and consequently to man [2]. Besides, their rapid migration towards groundwater or water surface by infiltration or streaming is quite possible. In all cases, the brutal release of these metals after a long period of accumulation, under the influence of a serious environmental change, could become a problem at Edea. The continuous exposure of Pb to the population of this locality is susceptible to cause health issues such as anaemia, renal deficiencies, damages to the central nervous system and encephalopathy [2]. The groups that are highly vulnerable and very sensitive to Pb toxicity are pregnant women, foetus and young children [14].

4. Conclusions

On the whole, environmental ecosystems of the Edea dumping sites are liable to copper and lead pollution, due to the composition of wastes. Their mobility, accumulation and transfer constitute a risk to human health through the contamination of the food chain, but also for the natural milieu. Due allowance being made for their non-biodegradable nature, there is a risk of rapid migration to groundwater and water surface, an accumulation in deep horizons and subsequent release into nearby ecosystems. This is already visible in water surface whose maximum concentrations are higher than WHO prescribed norms. Local populations are liable for chemical intoxications due to important and regular ingestion of Pb and Cu in near future, thus the interest to envisage depollution projects of these sites by the method of

phytoremediation.

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