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Full Length Research Paper

Plants diversity and phytoaccumulators identification on the Akouedo landfill (Abidjan, Côte d'Ivoire)

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Phytoremediation is an emerging technology to remediate contaminated soils. Their implementation in developing countries may be limited by the plant species used. To overcome this situation, plants from the Akouedo landfill have been inventoried in order to identify indigenous plants adapted to soil and environmental conditions. Two sampling zones have been defined, based on the waste dumping activities or not. Four plots (50 × 50 m^2) have been defined. The plant species collected were used to constitute vouchers for identification. Plants frequency occurrence was used to evaluate their relative importance, while the Shannon and evenness indices were calculated to characterize the diversity. The plant families and species identified were compared to those described as heavy metals phytoaccumulators in the literature. A total of 130 taxa belonging to 39 families have been recorded. The most frequent families (36.9% of the total taxa) were Poaceae, Euphorbiaceae and Cyperaceae. The dominant taxa on the old waste dumpsite having an average density superior to 5 plants/m^2 and occurring less frequently on the control site were *Alternanthera sessilis, Amaranthus spinosus, Cyperus rotundus, Cyperus iria, Eleusine indica, Euphorbia glomerifera, Ipomoea triloba, Portulaca oleracea* and *Trianthema portulacastrum.* These plant species may be indigenous phytoaccumulators on the Akouedo landfill.

Key words: Heavy metals, landfill, phytoaccumulators, phytoremediation, plants.

INTRODUCTION

Throughout the world, heavy metals pollute soils because of industrial and municipal wastes dumpsites or atmospheric deposition. This situation constitutes hazards to human and animal health (Maiti et al., 2004). Municipal solid waste is a major source of heavy metals contamination of soil (Miquel, 2001). The impacts of heavy metals in the environment differ according to the biosphere compartment (Thangavel and Subbhuraam, 2004) and depend on metals mobility, utilization by organisms or micro-organisms, adsorption, precipitation, etc. However, some plants growing on metals contaminated soils accumulate some at high levels (Xiong, 1998; Cobb et al., 2000; Benson and Ebong, 2005). These plants are considered to be phyto-accumulators. They may constitute serious health hazard if they are consumed, because of the toxicity of some metals to human being and animals (Knasmuller et al., 1998; Micieta and Murin, 1998; Baudouin et al., 2002; Ellis and Salt, 2003; Pillay et al., 2003).

Industrial development and demographic growth in the Abidjan district are responsible for potential waste generation. Waste production was evaluated to be 550 000 tons in 2000 (Kouadio et al., 2000). Now, it is around one million tons in that district. Approximately, 70% of these wastes have been disposed into the Akouedo landfill since four decades, causing soil pollution in this area. Kouamé et al. (2006) have characterized lead (Pb) and cadmium (Cd) in this landfill soil and their concentrations varied respectively between 10.3 to 1500 ppm, and 1 to 11.5 ppm. These metal-contaminated soils are used for peri-urban agriculture to produce edible crops (maize, okra, tomatoes and eggplants). Some of those plants may accumulate heavy metals and their

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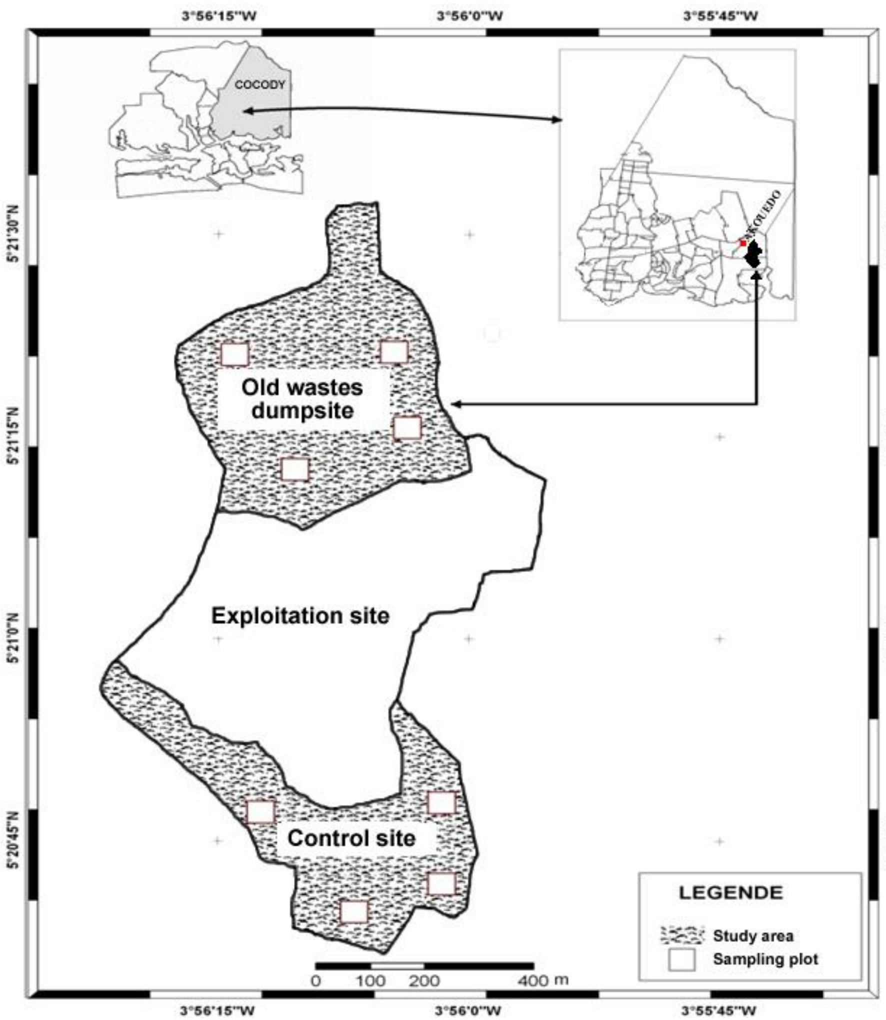

Figure 1. Sampling plots location on the study area.

consumption could contaminate the food chain. This in turn could constitute potential health implications to humans and animals consuming such crops (Ellis and Salt, 2003; Pillay et al., 2003).

Metals-contaminated soils are remediated by chemical, physical or biological techniques (McEldowney et al., 1993). The first two treatment methods have irreversible effects on soil biodiversity and properties that render them unusable for agriculture (Prabha and Loretta, 2007). Phytoremediation is one of the biological soil remediation technologies. It is a promising cost-effective and plant-based technology for heavy metals remediation (Raskin et al., 1994; Cunningham and Ow, 1996; Anoliefo et al., 2008). It may be attractive in tropical countries because of favourable climatic conditions for plants growth (Lombi et al., 2001). However, one of the limited factors affecting the implementation of this technology in Côte d'Ivoire is the difficulty associated with the growth of the plant species in use. The utilization of phytoaccumulation technology in Côte d'Ivoire needs identification of endogenous phytoaccumulators. In this context, the Akouedo landfill is a natural pressure area where phytoaccumulators could be detected. Therefore, this research was aimed at: (1) making the inventory of plant species on the Akouedo landfill site, (2) identifying potential phytoaccumulators and (3) analysing the plant ecology that constitutes the first steps in phytoremediation strategy.

MATERIALS AND METHODS

Study area

The Akouedo landfill is situated between 5°20'30" and 5°21'37" N and 3°55'52" and 3°56'30" W located in Abidjan District, near Akouedo village (Figure 1). It covers an area of about 153 ha. The climate of the zone, which is sub-equatorial, was characterized by four seasons: (1) a major dry season (December to March), (2) a major rainy season (April to July), (3) a minor dry season (August to September) and (4) a minor rainy season (October to November). The annual rainfall ranges from 1 040 to 2 079 mm, with an inter-

Table 1. Plant families identified with heavy metals phytoextraction capacity.

Family	Heavy metal	Reference
Acanthaceae	Ni	Reeves (2003)
Amaranthaceae	Cd, Fe, Zn, Cr, Ni	Prasad (2001); Moodley et al. (2007)
Asteraceae	Ni, As	Brooks (1998); Reeves (2003); Mahmud et al. (2008)
Commelinaceae	Ni	Reeves (2003)
Convolvulaceae	Ni	Rajakaruna and Bohm (2002)
Cyperaceae	Sn, B, Cd	Mushrifah et al. (2005); Adin and Çakir (2009); Sao et al. (2007)
Euphorbiaceae	Ni	Proctor et al. (1989); Baker et al. (1992); Rajakaruna and Bohm (2002); Reeves (2003)
Fabaceae	Ni	Rajakaruna and Bohm (2002) ; Reeves (2003)
Lamiaceae	Ni, Cu, Co	Rajakaruna and Bohm (2002); Brooks (1998)
Poaceae	Cd, Cu, Ni, Cr, Pb, Zn	Truong (1994); Huang and Cunningham (1996); Blaylock et al. (1997); Begonia et al. (1998); Ebbs and Kochian (1998); Chen et al. (2000)
Portulacaceae	Fe	Ebong et al. (2007)
Rubiaceae	Ni	Reeves (2003)
Solanaceae	Zn, Ni	Mohamed et al. (2003)
Tiliaceae	Ni	Brooks and Wither (1977a, 1977b); Reeves (2003)
Urticaceae	Cr	Shams et al. (2009)
Verbenaceae	Ni, As	Rajakaruna and Bohm (2002); Mahmud et al. (2008)

annual of 1 364 mm average. The maximum temperatures range from 25 to 33°C, while the minimum varies between 22 and 24°C. The sunshine ranges from 117 h (August) and 224 h (November). The average relative humidity varies between 78% (January) and 87% (August). Evaporation is very important in the major dry season with a peak in March (65 mm). In August, the evaporation decreased significantly and can reach 25.7 mm. Moreover, the soil of the study area was contaminated with inorganic pollutants. In the superficial stratum (less than 50 cm depth), the average concentrations of zinc (Zn), chromium (Cr), cadmium (Cd), lead (Pb), iron (Fe), and copper (Cu) were respectively of 250, 50, 5, 140, 1 400 and 80 ppm. The mean value of pH was 8.25 (Kouamé et al., 2006).

Inventory and identification of taxa

Two sampling zones have been defined according to their characteristics linked to waste dumping site or not on them. An old waste dumpsite and a control site that has never received waste were considered for the plants inventory. Plants recording were done in quadrats established on the study area. These quadrats were established after a visual visit of the site in order to record a maximum representative species. Eight plots of 50 m by side (2500 m^2) were established on the site. Each plot was divided into hundred quadrats of 25 m^2. Ten of these quadrats were randomly selected for inventory. In each quadrat, plants were collected to constitute vouchers. These vouchers were dried in an oven at 30°C for 72 h, and then taken to the “Centre National de Floristique” for identification. Moreover, on each of the sampling quadrats, 5 squares (one in each corner (4) and one in the centre (1) of 1 m^2 were established to evaluate the taxa density. These taxa density were calculated considering quadrat’s surface.

Phytoaccumulators identification

The phytoaccumulators were identified in the plant samples according to plants characterized as phytoaccumulators in the literature (Tables 1 and 2).

Data analysis

A data base was constituted with the plant taxa collected and identified. The taxonomic richness and diversity were analysed using frequency of occurrence (F), Shannon (H’) and evenness (E) indices. Sorensen index (K) was also used to comprehend the flora community’s similarity of the sampling zones. These different parameters were calculated according to the following formulas:

$$F = \frac{Fix100}{Ft} \qquad (1)$$

Where, *Fi* is the total releve contained in the taxon *i* and *Ft* is the total number of releve.

$$H' = -\sum_{i=1}^{S} (pix \log_2(pi)) \qquad (2)$$

Where, *S* is the total number of taxa and *pi* is the proportion of individual of the taxon *i* in relation to the total number of individuals.

$$E = \frac{H'}{\log_2(S)} \qquad (3)$$

$$K = \frac{2cx100}{a+b} \qquad (4)$$

Where, *a* is the total number of taxa on the old waste dumpsite; *b*

Table 2. Plant species identified with heavy metals phytoextraction capacity.

Plant species	Heavy metal	Concentration (mg/kg dry weight)	Reference
Alternanthera sessilis	Cd	Root: 37; stem: 38; leaf: 40	Prasad (2001)
	Zn	Root:150; stem:190; leaf: 100	
	Fe	Root: 280; stem: 275; leaf: 300	
Amaranthus spinosus	Cd	Root: 33; stem: 31; leaf: 34	Prasad (2001)
		Root: 50.8; shoot: 24.5	Abe et al. (2008)
	Zn	Root: 125; stem: 120; leaf:128	Prasad (2001)
	Fe	Root: 278; stem: 225; leaf: 301	
Amaranthus viridis	Cd	Root: 61.4 ; shoot: 24.8	Abe et al. (2008)
Bidens pilosa	Cd	Root: 7.7; shoot: 17.0	Abe et al. (2008)
Chromolaena odorata	Cd	Root: 2.99; shoot: 14.1	Boonlert (2008)
		2.90 - 5.09	Adie and Osibanjo (2010)
	Zn	Root: 3.01; shoot: 278	Boonlert (2008)
	Pb	400-1210	Adie and Osibanjo (2010)
Cynodon dactylon	Pb	Root: 50; shoot: 25	Abou-Shanab et al. (2007)
	Zn	Root: 225; shoot: 90	
	Cr	Root: 155; shoot: 6000	
	Cu	Root: 80; shoot: 45	
	B	Root: 95; shoot: 202	Aydin and Çakir (2009)
Cyperus rotundus	Sn	Root: 13.40 ±1.16; stem: 1.15±0.48; leaf: 2.03±0.71	Mushrifah et al. (2005)
	B	Root: 71; shoot: 229	Aydin and Çakir (2009)
	Cd	Root: 2.17±0.04; shoot: 1.14±0.03	Sao et al. (2007)
Echinochloa crus-galli	Cd	Root: 63.6; shoot: 9.0	Abe et al. (2008)
	B	Root: 49; shoot: 226	Aydin and Çakir (2009)
Eleusine indica	Pb	4800 - 7890	Adie and Osibanjo (2010)
	Cd	2.90 - 7.40	
	Pb	Root: 9.81± 0.27; stem: 5.02 ± 0.53; leaf: 0.95 ± 0.08	Akinola and Adedeji (2007)
Panicum maximum		1090-1730	Adie and Osibanjo (2010)
	Cd	1.99-6.85	Adie and Osibanjo (2010)
Portulaca oleraceae	Cd	Root: 55.6; shoot: 4.4	Abe et al. (2008)
	Cu	Root: 17.4; shoot: 12.9	Wei and Zhou (2008)
	Zn	Root: 10.34; shoot: 75	
Talinum triangulare	Cd	Leaf: 0.10 - 0.30	Ebong et al. (2007)
	Pb	Leaf: 0.33 - 1.55	
	Ni	Leaf: 0.05 - 0.45	
	Fe	Leaf: 226.43 - 260.00	
	Zn	Leaf: 2.20 - 29.95	
Zea mays	Pb	Root: 10000; shoot: 15	Abou-Shanab et al. (2007)
		Shoot: 938	Hernandez-Allica et al. (2008)
	Zn	Root: 5000; shoot: 85	Abou-Shanab et al. (2007)
		Shoot: 2276	Hernandez-Allica et al. (2008)
	Cu	Root: 85; shoot: 25	Abou-Shanab et al. (2007)
		Shoot: 18	Hernandez-Allica et al. (2008)
	Cr	Root: 6000; shoot: 145	Abou-Shanab et al. (2007)
	Cd	Leaf: 10; seed: 0.2	Granato et al. (2004)

Table 3. Plants inventoried on the old wastes dumpsite (AD) and on the control site (SC).

Family	Taxa	Code	AD	%Oc	SC	%Oc
Poaceae	*Acroceras zizanioides* (Kunth) Dandy	Acziz	-	0	+	25
	Axonopus compressus (SW) P. Beauv.	Axcom	-	0	+	50
	Bambusa vulgaris Schrad.ex.J.C.Wendl	Bavul	-	0	+	25
	Brachiaria sp. sp. Grieb	Brach	+	25	+	50
	Brachiaria villosa (Lam.) A.Camus	Brvil	-	0	+	25
	Digitaria horizontalis Willd.	Dihor	+	100	+	100
	Eleusine indica (L.) Gaertn.	Elind	+	100	+	25
	Panicum brevifolium L.	Pabre	-	0	+	100
	Panicum laxum Sw.	Palax	-	0	+	100
	Panicum maximum Jacq.	Pamax	+	25	+	100
	Paspalum scrobiculatum L.	Pascr	-	0	+	25
	Sporobolus pyramidalis (P.) Beauv.	Sppyr	-	0	+	25
	Cenchrus biflorus Roxb.	Cebif	+	25	-	0
	Cynodon dactylon (L.) Pers.	Cydac	+	50	-	0
	Dactyloctenium aegyptium (L.) Willd.	Daaeg	+	25	-	0
	Echinochloa colona (L.) Link	Eccol	+	25	-	0
	Echinochloa crus-galli (L.) P. Beauv.	Eccru	+	25	-	0
	Eragrostis ciliaris (L.) R. Br.	Ercil	-	0	+	25
	Zea mays L.	Zemay	+	100	+	25
	Eragrostis tenella (L.) Beauv. ex Roemer et J.A. Schultes	Erten	+	50	-	0
	Pennisetum polystachion (L.) Schult	Pepol	+	25	-	0
Euphorbiaceae	*Croton hirtus* L'herit	Crhir	-	0	+	100
	Croton lobatus L.	Crlob	-	0	+	50
	Phyllanthus amarus Schumach. & Thonn.	Phama	+	100	+	100
	Phyllanthus odontadenius Müll. Arg.	Phodo	+	25	-	0
	Manihot esculenta Crantz	Maesc	+	25	+	100
	Microcca mercurialis (L.) Benth.	Mimer	-	0	+	25
	Euphorbia prostrata Aiton	Eupro	+	75	-	0
	Euphorbia glomerifera (Millsp.) L.C.Wheeler	Euglo	+	100	-	0
	Euphorbia heterophylla L.	Euhet	+	25	-	0
	Euphorbia hirta L.	Euhir	+	50	+	25
	Euphorbia hyssopifolia L.	Euhys	+	25	-	0
	Euphorbia thymifolia L.	Euthm	+	25	-	0
	Breynia angustifolia Hook. f.	Brang	-	0	+	100
	Tragia benthami Bak.	Trben	-	0	+	25
Cyperaceae	*Pycreus polystachyos* (Rottb.) P. Beauv.	Pypol	+	25	-	0
	Pycreus lanceolatus (Poir.) C. B. Clarke	Pylan	+	25	-	0
	Cyperus rotundus L.	Cyrot	+	100	+	25
	Cyperus distans L. f.	Cydis	+	50	-	0
	Cyperus diffusus subsp. *Buchholzii* (Boeck.) Kük.	Cydif	-	0	+	25
	Cyperus iria L.	Cyiri	+	75	-	0
	Cyperus dilatatus Schumach. & Thonn.	Cydil	+	100	+	75
	Cyperus exaltatus Retz.	Cyexa	+	25	-	0
	Fimbristylis cymosa R. Br.	Ficym	+	25	-	0
	Mariscus sp. Vahl	Maris	+	50	-	0
	Mariscus cylindristachyus Steud.	Macy	+	50	+	100
	Mariscus flabelliformis Kunth	Mafla	-	0	+	100
	Mariscus longibracteatus Cherm.	Malon	+	25	+	25

Table 3. Continued.

Asteraceae	*Eclipta prostrata* (L.) L.	Ecpro	+	25	-	0
	Emilia praetermissa Milne-Redh.	Empra	-	0	+	100
	Aspilia africana (Pers.) C.D.Adams	Asafr	-	0	+	25
	Chromolaena odorata (L.) R.M. King & H. Rob.	Chodo	-	0	+	100
	Mikania cordata (Burm. f.) B. L. Rob.	Micor	-	0	+	75
	Tridax procumbens L.	Trpro	+	50	+	25
	Vernonia cinerea (L.) Less.	Vecin	+	25	+	75
	Ageratum conyzoides L.	Agcon	+	50	-	0
	Bidens pilosa L.	Bipil	+	25	+	50
Rubiaceae	*Pentodon pentandrus* (Schumach. & Thonn.) Vatke	Pepen	+	50	-	0
	Borreria latifolia (Aubl.) K. Schum.	Bolat	-	0	+	100
	Borreria verticillata (L.) G. Mey.	Bover	-	0	+	25
	Diodia rubricosa Hiern.	Dirub	-	0	+	25
	Oldenlandia affinis (Roem. & Schult.) DC.	Olafi	-	0	+	100
	Oldenlandia corymbosa L.	Olcor	+	100	+	75
	Mitracarpus scaber Zucc.	Misca	+	25	-	0
Amaranthaceae	*Alternanthera sessilis* (L.) DC.	Alses	+	75	-	0
	Amaranthus spinosus (L.)	Amspi	+	100	-	0
	Amaranthus viridis (L.)	Amvir	+	25	-	0
	Celosia trigyna (L.)	Cetri	-	0	+	75
	Cyathula prostrata (L.) Blume.	Cypro	-	0	+	100
Malvaceae	*Hibiscus sabdariffa* (L.)	Hisab	-	0	+	25
	Hibiscus surattensis (L.)	Hisur	-	0	+	50
	Sida acuta Burm. f.	Siacu	-	0	+	25
	Sida linifolia Juss. excav.	Silin	-	0	+	25
	Albelmoschus esculentus (L.)	Abesc	+	50	-	0
Solanaceae	*Solanum lycopersicum* (L.)	Solyc	-	0	+	25
	Solanum melongena (L.)	Somel	-	0	+	50
	Solanum americanum (L.)	Soame	-	0	+	25
	Physalis angulata (L.)	Phang	-	0	+	25
	Capsicum frutescens (L.)	Cafru	+	50	-	0
Commelinaceae	*Commelina benghalensis* (P.Beauv.) Kunth	Coben	+	25	-	0
	Commelina diffusa Burm. f.	Codif	+	25	+	50
	Commelina erecta L.	Coere	-	0	+	25
	Palisota hirsuta (Thunb.) K. Schum.	Pahir	-	0	+	50
Fabaceae	*Vigna unguiculata* (L.) Walp.	Viung	+	25	-	0
	Sesbania sesban (L.) Merr.	Seses	+	25	-	0
	Calopogonium mucunoides Desv.	Camuc	-	0	+	50
	Centrosema pubescens Benth.	Cepub	-	0	+	25
Convolvulaceae	*Ipomoea involucrata* P. Beauv.	Ipinv	-	0	+	100
	Ipomoea mauritiana Jacq.	Ipmau	-	0	+	25
	Ipomoea triloba L.	Iptri	+	100	-	0
Cucurbitaceae	*Momordica charantia* L.	Mocha	-	0	+	100
	Luffa cylindrica (L.) M. Roem.	Lucyl	-	0	+	25
	Cucurbita maxima Duchesne	Cumax	+	100	-	0

Table 3. Continued.

Onagraceae	*Ludwigia abyssinica* A. Rich.	Luaby	+	50	-	0
	Ludwigia erecta (L.) Hara	Luere	+	50	+	25
	Ludwigia octovalvis (Jacq.) P. H. Raven	Luoct	+	25	-	0
Verbenaceae	*Clerodendrum* sp. L.	Clero	-	0	+	25
	Clerodendrum volubile P. Beauv.	Clvol	-	0	+	50
	Latana camara L.	Lacam	-	0	+	75
Acanthaceae	*Asystasia gangetica* (L.) T. Anderson	Asgan	-	0	+	100
	Thunbergia erecta (Benth.) T.	There	-	0	+	25
Araceae	*Colocasia esculenta* (L.) Schott	Coesc	+	75	-	0
	Cercestis afzelii Schott	Ceafz	-	0	+	25
Capparidaceae	*Cleome ciliata* Schumacher	Clcil	+	100	+	75
	Cleome gynandra L.	Clgyn	+	25	-	0
Dioscoreaceae	*Dioscorea minutiflora* Engl.	Dimin	-	0	+	25
	Dioscorea smilacifolia De Wild.	Dismi	-	0	+	25
Portulacaceae	*Portulaca oleraceae* L.	Poole	+	100	+	25
	Talinum triangulare (Jacq.) Willd.	Tatri	+	100	+	100
Tiliaceae	*Corchorus aestuans* L.	Coaes	+	25	+	25
	Triumfetta rhomboidea Jacq.	Trrho	-	0	+	75
Apocynaceae	*Catharanthus roseus* L. G.	Caros	-	0	+	25
Asclepiadaceae	*Pergularia daemia* (Forssk.) Chiov.	Pedae	-	0	+	25
Bignoniaceae	*Tecoma stans* (L.) Juss. ex Kunth	Testa	-	0	+	25
Bombacaceae	*Adansonia digitata* L.	Addig	+	25	-	0
Caesalpiniaceae	*Cassia occidentalis* L.	Caocc	+	25	-	0
Combretaceae	*Combretum paniculatum* Vent.	Copan	-	0	+	25
Connaraceae	*Cnestis ferruginea* DC.	Cnfer	-	0	+	25
Ficoidaceae	*Trianthema portulacastrum* L.	Trpor	+	100	-	0
Flagellariaceae	*Flagellaria guineensis* Schumacher	Flgui	-	0	+	25
Lamiaceae	*Solenostemon monostachyus* (P. Beauv.) Briq.	Somon	+	50	-	0
Loganiaceae	*Spigelia anthelmia* L.	Spant	-	0	+	25
Molluginaceae	*Mollugo nudicaulis* Lam.	Monud	-	0	+	50
Musaceae	*Musa paradisiaca* L.	Mupar	+	25	+	50
Nyctaginaceae	*Boerhavia diffusa* L.	Bodif	+	50	+	100
Passifloraceae	*Passiflora foetida* L.	Pafoe	+	25	-	0
Pedaliaceae	*Sesamum radiatum* Schumach. & Thonn.	Serad	-	0	+	25
Periplococeae	*Parquetina nigrescens* (Afzel.) Bullock	Panig	-	0	+	25
Ulmaceae	*Trema guineensis* (Schum. & Thonn.) Ficalho	Trgui	-	0	+	25
Urticaceae	*Laportea aestuans* (L.) Chew	Laaes	+	100	+	50

is the total number of taxa on the control site; *c* is the total number of common taxa. The relative importance of taxa was examined with the frequency of occurrence:tThe dominant taxa (F > 50%), secondary taxa (25% < F ≤ 50%) and rare taxa (F ≤ 25%) were defined. The Mann-Whitney test was used to assess differences in taxonomic richness and Shannon index at $p= 0.05$ of significance level. The statistical analysis was performed with the software package STATISTICA 7.1.

RESULTS

A total of 130 plant taxa belonging to 39 families were recorded (Table 3). The most widely represented families(36.9% of total taxa) were Poaceae (21), Euphorbiaceae (14) and Cyperaceae (13). The Sorensen's index value obtained (K = 32.2% <50%)

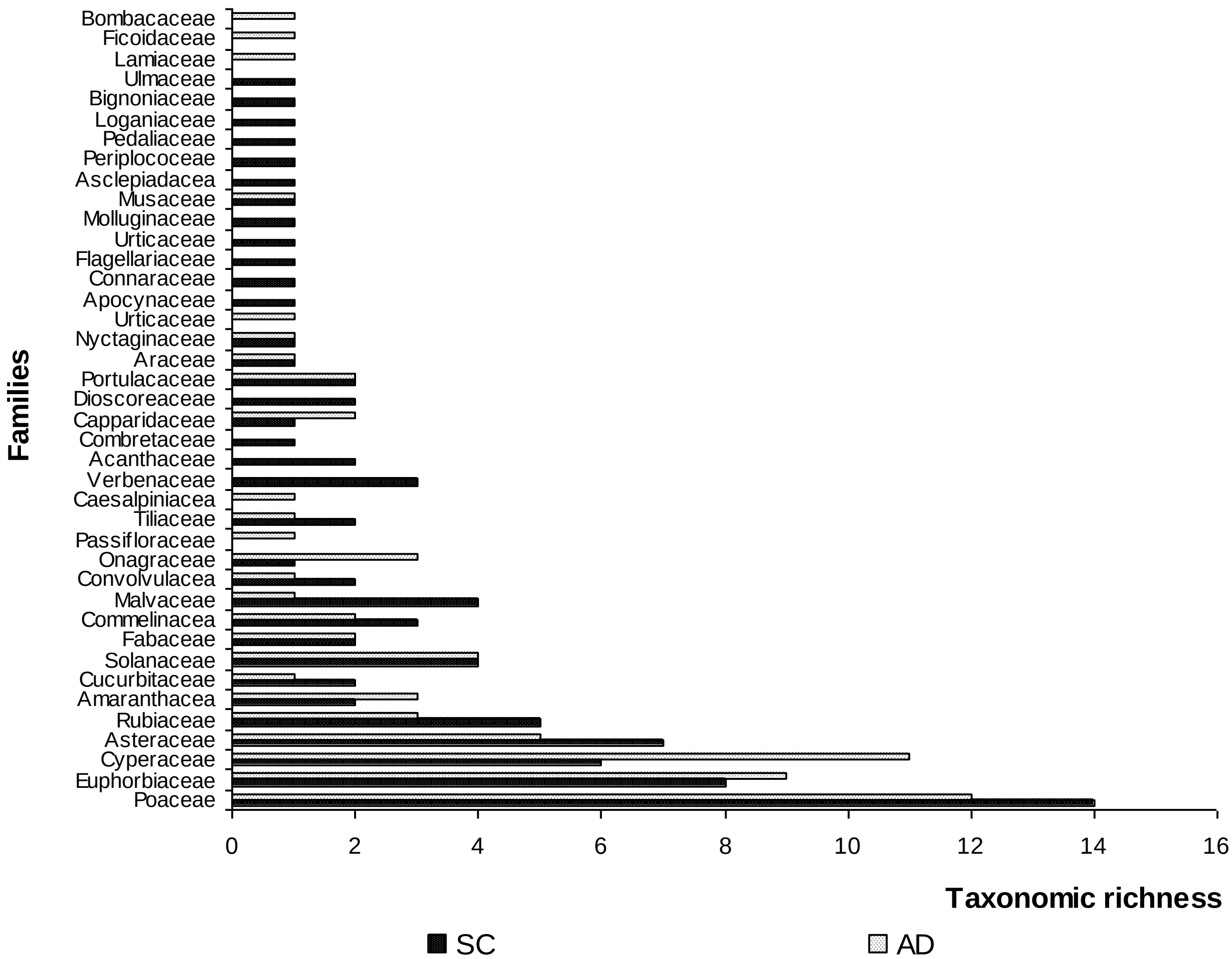

Figure 2. Taxonomic richness of families grown on the waste dumpsite (AD) and on the control site (SC).

indicates a difference between plant communities on the two zones investigated. Among the plant families identified, 20 of them were both present on the control and the waste dumping site. However, five families (Bombacaceae, Caesalpiniaceae, Ficoidaceae, Lamiaceae, Passifloraceae) were specific to the waste dumpsite, and the others 14 (Verbenaceae, Acanthaceae, Dioscoreaceae, Apocynaceae, Asclepiadaceae, Bignoniaceae, Combretaceae, Connaraceae, Flagellariaceae, Loganiaceae, Molluginaceae, Pedaliaceae, Periplocaceae, Ulmaceae) were only founded on the control site. Considering the taxa, 25 of them were common to the two zones investigated. The characteristic taxa of the waste dumpsite and the control site were respectively 43 and 62. On the waste dumpsite, 68 taxa distributed among 25 families were recorded.

The families of Poaceae (12), Cyperaceae (11) and Euphorbiaceae (9) with 47% of the taxonomic richness were represented in high number (Figure 2). The most frequent taxa (F > 50%) were *Digitaria horizontalis*, *Eleusine indica*, *Zea mays*, *Phyllanthus amarus*, *Euphorbia prostrata*, *E. glomerifera*, *Cyperus rotundus*, *C. iria, C. dilatatus, Oldenlendia corymbosa, Solanum lycopersicum, Alternanthera sessilis, Amaranthus spinosus, Ipomoea triloba, Cleome ciliata, Portulaca oleraceae, Talinum triangulare, Colocasia esculenta, Laportea aestuans* and *Trianthema portulacastrum*. The secondary taxa (25% < F ≤ 50%) group included *Cynodon dactylon, Ergarostis tenella, Euphorbia hirta, Cyperus distans, Mariscus* sp., *Mariscus cylindristachyus, Tridax procumbens, Ageratum conyzoides*, *Pentodon pentandrus*, *Luffa cylindrica*, *Solanum melongena*, *Solanum americanum, Abelmoschus esculentus, Ludwigia abyssinica, Ludwigia erecta, Boerhavia diffusa* and *Solenostemon monostachyus.*

On the control site, 87 taxa distributed over 34 families were recorded. The most frequent families were the Poaceae (14), Euphorbiaceae (8) and Asteraceae (7) (Figure 2). The dominant taxa, representing 34.49% of the taxonomic richness were *Digitaria horizontalis, Panicum brevifolium, Panicum laxum, Panicum maximum,*

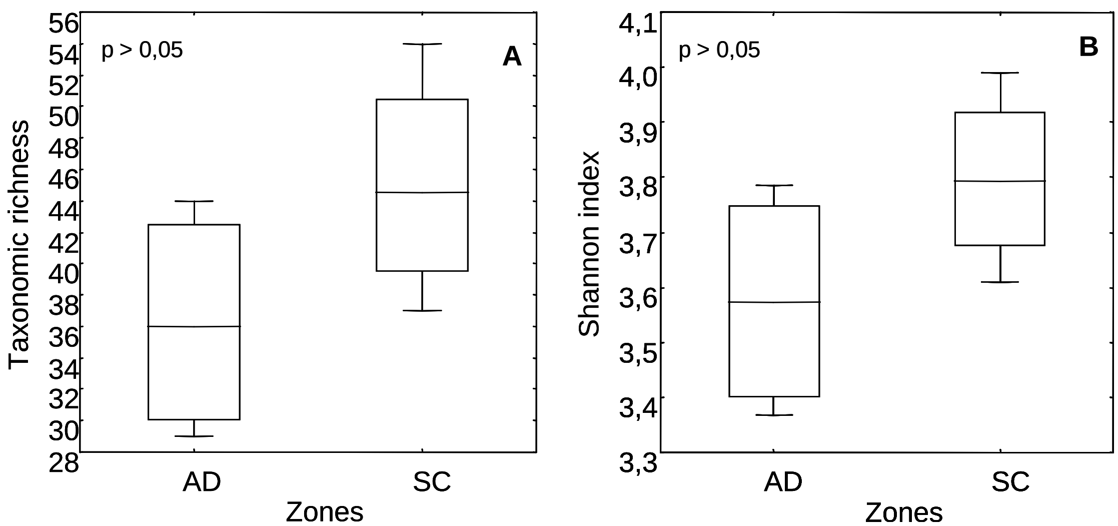

Figure 3. Variation of the taxonomic richness (A) and Shannon diversity index (B).

Croton hirtus, Phyllanthus amarus, Manihot esculenta, Breynia angustifolia, Cyperus dilatatus, Mariscus cylindristachyus, Mariscus flabelliformis, Emilia praetermissa, Chromolaena odorata, Mikania cordata, Vernonia cinerea, Borreria latifolia, Oldenlandia affinis, Oldenlandia corymbosa, Celosia trigyna, Cyathula prostrata, Solanum melongena, Solanum americanum, Physalis angulata, Ipomoea involucrata, Lantana camara, Asystasia gangetica, Cleome ciliata, Talinum triangulare, Triumfetta rhomboidea and *Boerhavia diffusa*.

Moreover, the secondary taxa included *Axonopus compressus*, *Brachiaria* sp., *Croton lobatus*, *Bidens pilosa*, *Hibiscus surattensis*, *Commelina diffusa*, *Palisota hirsuta*, *Calopogonium mucunoides*, *Clerodendrum volubile*, *Mollugo nudicaulis*, *Musa paradisiaca* and *Laportea aestuans*.

The taxonomic richness (Figure 3A) of the plants varied between 29 and 44 taxa, and between 37 and 54 taxa, respectively on the waste dumpsite and the control site.

Relatively, to the Shannon index diversity (Figure 3B), it ranged from 3.36 and 3.78 bits / ind. (waste dumpsite) and from 3.61 and 3.98 bits / ind. (control site). Significant differences in taxon richness (R) and Shannon diversity index (H') were not observed between the two sampling areas (Mann-Whitney U test: $p> 0.05$). However, the zones investigated presented high diversity.Regarding the evenness index (E = 1) obtained, it indicated homogeneous flora distribution. The average density of the most frequently observed taxa on the old waste dumpsite and rare on the control site, ranged from 1 ± 1 plant/m^2 (*Colocasia esculenta, Euphorbia glomerifera, C. dactylon*) to 67 ± 36 plants/m^2 (*A. spinosus*) (Figure 4). The other taxa *T. portulacastrum* (17 ± 20 plants/m^2), *Cyperus iria* (17 ± 30 plants/m^2), *Ipomoea triloba* (8 ± 7 plants/m^2), *P. oleraceae* (6 ± 5 plants/m^2) *Alternanathera sessilis* (5 ± 6 plants/m^2), *Eleusine indica* (4 ± 5 plants/m^2), *Mariscus* sp. (2 ± 3 plants/m^2), *C. rotundus* (2 ± 1 plants/m^2), *Pentodon pentandrus* (1 ± 3 plants/m^2) and *Eragrostis tenella* (1 ± 2 plants/m^2) presented varied average density. Some plant species identified on the waste dumpsite presented phytoextraction capacity (Table 2). These plant species belong to the families of Poaceae (*C. dactylon, Echinochloa crus-galli, Eleusine indica, Panicum maximum, Zea mays),* Amaranthaceae *(A. sessilis, A. spinosus, Amaranthus viridis),* Asteraceae *(Bidens pilosa, Chromolaena odorata),* Portulacaceae *(P. oleraceae, Talinum triangulare)* and Cyperaceae *(C. rotundus).* The family of Poaceae is the well represented and is reported to accumulate preferentially Pb and Cd. In addition, the other families present ability for Cd phytoextraction.

DISCUSSION

The plant species inventoried on Akouedo landfill have permitted the identification of 130 taxa belonging to 39 families. These taxa were distributed as follow: 68 and 87 taxa were recorded on the old waste dumpsite and the control area respectively. The taxonomic richness and the diversity of the two zones investigated were not significantly different (Mann-Whitney U test: $p> 0.05$). The high diversity index values reveal the trend of a high floristic diversity. This result could be explained by cessation of waste spreading on the old waste dumpsite that has permitted the transformation of the waste into stabilised humus as on the control site. The relative low taxonomic richness encountered on the old waste dumpsite may be explained by the pressure on the surface: presence of pollutants and gas. According to Maurice et al. (1995), taxonomic diversity decreased with landfill age. Moreover, the Sorensen coefficient indicates

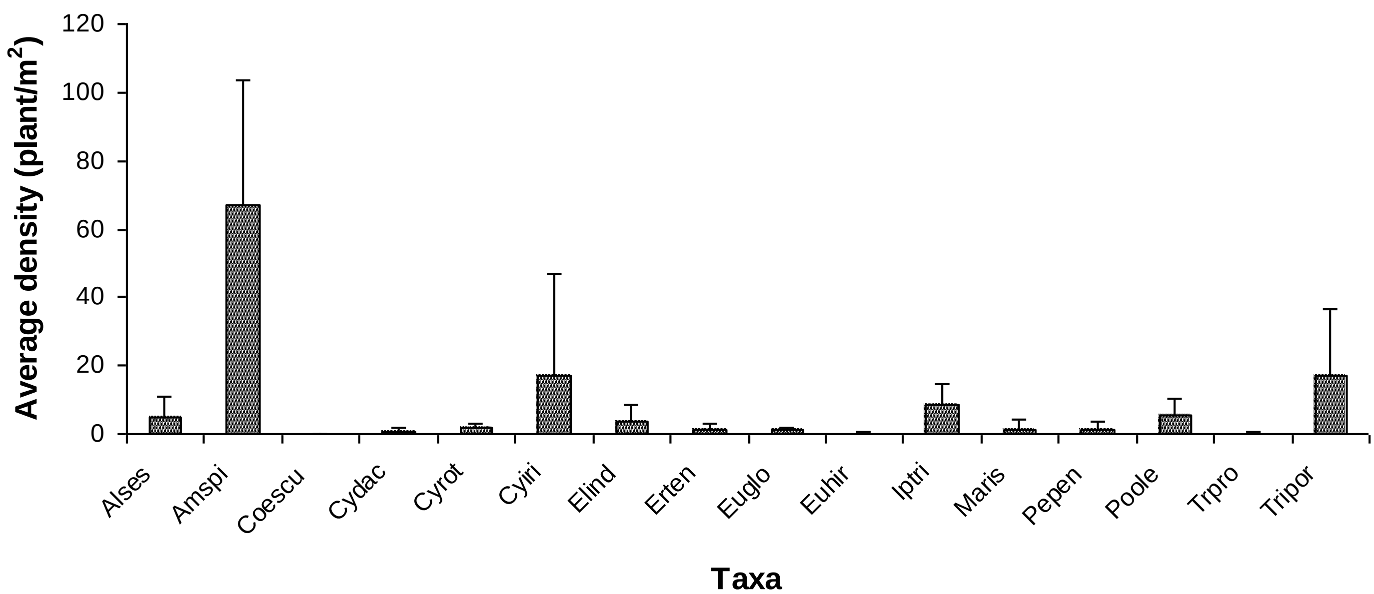

Figure 4. Average density of dominant taxa on the waste dumpsite (AD) and rare on the control site (SC).

a difference between the plant communities established on the two areas investigated. This difference could be due to the local conditions such as temperature, drainage, nature of soils and gas emissions (Nagendra et al., 2006). The presence of elevated number of exclusives plants families and taxa could also be due to these specific conditions prevailing over the sites. However, 20 families and 25 taxa were common to the two studied area. Plants presenting ruderary characters (Aké-Assi, 2001, 2002) may explain their presence on the two sites.

Relative to the plants capacities to contribute to metals extraction in polluted soils, more than 400 species covering over 45 families have been identified as hypercaccumulators (Salt et al., 1998; Reeves and Baker, 2000; Dushenkov, 2003). Among these families, were some collected on the Akouedo landfill (Amaranthaceae, Asteraceae, Commelinaceae, Convolvulaceae, Cyperaceae, Euphorbiaceae, Fabaceae, Lamiaceae, Malvaceae, Poaceae, Portulaceae, Rubiaceae, Solanaceae, Tiliaceae and Urticaceae). Moreover, over 60% of the families recorded on the old waste dumpsite were also classified as phytoaccumulators. The presence of these plant families on this site could be explained by the suitable climatic conditions. On the other hand, their presence on the control site could be due to the transportation of the plants grains on the study area. Ensley et al. (1997) indicated that the family of Euphorbiaceae was predominant in tropical area. Among these families, the Fabaceae was considered by Thangavel and Subbhuraam (2004) as the first hyperaccumlators.

According to Prasad and Freitas (2003), the dominant hyperaccumlators families included Asteraceae, Brassicaceae, Caryophylaceae, Cyperaceae, Cunouniaceae, Fabaceae, Flacourtiaceae, Lamiaceae, Poaceae, Violaceae and Euphorbiaceae. On the old waste dumpsite, six (Asteraceae, Cyperaceae, Fabaceae, Lamiaceae, Poaceae and Euphorbiaceae) of these dominant families were recorded. Most plant species grown on this site present capacity to tolerate heavy metals accumulation (Kouame et al., 2006). The high abundance of phytoaccumulators on this site demonstrates this capacity. In this group, Ni phytoaccumulators constitute more than 80%. The dominance of Ni phytoaccumulators could be explained by their proportion in the world. In fact, Thangavel and Subbhuraam (2004) noted that over two thirds of the species recorded are recognized as Ni hyperaccumulators. They represented approximately 300 species according to Prasad and Freitas (2003) and Prasad (2004). Regarding the taxa identified, several studies have confirmed their phytoaccumulation capacity (Prasad, 2001). These plants (*A. sessilis, A. spinosus, A. viridis, Bidens pilosa, C. odorata, C. dactylon, C. rotundus, Echinochloa crus-galli, E. indica, P. maximum, P. oleraceae*) were suitable for phytoextraction of Cd, Zn, Fe, Pb and Cu contaminated soils.

Conclusion

The Akouedo landfill presented high floristic diversity. In total, 130 taxa were distributed into 39 families have been listed. The most frequent families were Poaceae, Euphorbiaceae and Cyperaceae. The dominant taxa (F ≥ 50%) on the old waste dumping site with high average density (≥ 5 plants/m^2) and occurred less frequently (F ≤

25%) on the control zone are *A. sessilis, A. spinosus, C. rotundus, C. iria, E. indica, E. glomerifera, Ipomoea triloba, P. oleracea* and *T. portulacastrum.* Among these taxa, *A. spinosus*, *C. iria* and *T. portulacastrum* presented the highest mean density. These plant families and taxa are suggested as possible phytoaccumulators.

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REFERENCES

Abe T, Fukami M, Ogasawara M (2008). Cadmium accumulation in the shoots and roots of 93 weed species. Soil Sci. Plant Nutr. 54:566-573.

Abou-Shanab R, Ghanem N, Ghanem K, Al-Kolaibe A (2007). Phytoremediation potential of crop and wild plants for multi-metals contaminated soils. Res. J. Agric. Biol. Sci. 3(5):370-376.

Adie GU, Osibanjo O (2010). Accumulation of lead and cadmium by four tropical forage weeds found in the premises of an automobile battery manufacturing company in Nigeria. Toxicol. Environ. Chem. 92(1):39-49.

Aké-Assi L (2001). Flora of Côte d'Ivoire: systematic catalog, biogeography and ecology. Conservation and botanical garden., Switzerland, Geneva. Boissiera 57.

Aké-Assi L (2002). Flora of Côte d'Ivoire: systematic catalog, biogeography and ecology. Conservation and botanical garden., Switzerland, Geneva. Boissiera 58.

Akinola MO, Adedeji OA (2007). Assessment of lead concentration in *Panicum maximum* growing along the Lagos-Ibadan expressway, Nigeria. Afr. J. Sci. Technol. 8(2):97-102.

Anoliefo GO, Ikhajiagbe B, Okonokhua BO, Edegbai BO, Obasuji DC (2008). Metal tolerant species distribution and richness in and around the metal based industries: possible candidates for phytoremediation. Afr. J. Environ. Sci. Technol. 2(11):360-370.

Aydin M, Çakir F (2009). Research on weed species for phytoremediation of boron polluted soil. Afr. J. Biotechnol. 8(18):4514-4518.

Baker AJM, Proctor J, Reeves RD (1992). The vegetation of ultramafic (Serpentine) soils. Proceedings of the first international conference on Serpentine ecology, University of California, Davis, June 1991. Intercept, Hampshire, UK. pp 19-22.

Baudouin C, Charveron M, Tarrouse R, Gall Y (2002). Environmental pollutants and skin cancer. Cell. Biol. Toxicol. 18:341-348.

Begonia GB, Davis CD, Begonia MFT, Gray CN (1998). Growth responses of Indian mustard [*Brassica juncea* (L.) Czern] and its phytoextraction of lead from a contaminated soil. Bull. Environ. Contam. Toxicol. 61:38-43.

Benson NU, Ebong GA (2005). Heavy metals in vegetables commonly grown in garden ultisol. J. Sustain. Trop. Agric. Res. 16:77-80.

Blaylock MJ, Salt DE, Dushenkov S, Zakharova O, Gussman C, Kapulnik Y, Ensley BD, Raskin I (1997). Enhanced accumulation of Pb in Indian mustard by soil-applied chelating agents. Environ. Sci. Technol. 81(3):860-865.

Boonlert S (2008). Phytoremediation of Cd and Zn contaminated soil by *Chromolaena odorata*. Thesis for Master of Science. Mahidol University.

Brooks RR, Wither ED (1977a). Nickel hyperaccumulation by *Rinorea bengalenis* (Wall.). J. Geochem. Explor. 7:295-300.

Brooks RR, Wither ED (1977b). Cobalt and Nickel in *Rinorea* species. Plant Soil 47:707-712.

Brooks RR (1998). Plants that hyperaccumulate heavy metals. (eds.) Wallingford, UK: CAB International.

Chen HM, Zheng CR, Tu C, Shen ZG (2000). Chemical methods and phytoremediation of soil contaminated with heavy metals. Chemosphere 4:229-234.

Cobb GP, Sands K, Waters M, Wilson BG, Dorward-King E (2000). Accumulation of heavy metals by vegetables grown in mines wastes. Environ. Toxicol. 19:600-607.

Cunningham SD, Ow DW (1996). Promises and prospects of phytoremediation. Plant Physiol. 110:715-719.

Dushenkov S (2003). Trends in phytoremediation of radionuclides. Plant Soil 249:167-175.

Ebbs SD, Kochian LV (1998). Phytoextraction of zinc by oat (*Avena sativa*), barley (*Hordeum vulgare*) and indian mustard (*Brassica juncea*). Environ. Sci. Technol. 32(6):802-806.

Ebong GA, Etuk HS, Johnson AS (2007). Heavy metals accumulation by *Talinum triangulare* grown on waste dumpsites in Uyo metropolis, Akwa Ibom State, Nigeria. J. Appl. Sci. 7(10):1404-1409.

Ellis DR, Salt DE (2003). Plants, selenium and human health. Curr. Opin. Plant Biol. 6:273-279.

Ensley BD, Raskin I, Salt DE (1997). Phytoremediation applications for removing heavy metal contamination from soil and water. In: Biotechnology in the Sustainable Environment. Sayler Plenum Press, New York.

Granato TC, Pietz RI, Knafl GJ, Carlson-Jr CR, Tata P, Lue-Hing C (2004). Trace element concentrations in soil, corn leaves, and gain after cessation of biosolids applications. J. Environ. Qual. 33:2078-2089.

Hernandez-Allica J, Becerril JM, Garbisu C (2008). Assessment of the phytoextraction potential of high biomass crop plants. Environ. Pollut. 152:32-40.

Huang JW, Cunningham SD (1996). Lead phytoextraction: species variation in lead uptake and translocation. New Phytol. 134:75-84.

Knasmuller S, Gottmann E, Steinkellner H, Fomin A, Pickl C, Paschke A (1998). Detection of genotoxic effects of heavy metal contaminated soils with plant bioassays. Mutat. Res. 420:7-48.

Kouadio G, Dongui B, Trokourey A (2000). Determination of the chemical pollution of the area of the discharge Akouédo (Abidjan-Côte d'Ivoire). Rev. Ivoir. Sci. Technol. A01:34-41.

Kouamé KI, Goné DL, Savané I, Kouassi EA, Koffi K, Goula BTA, Diallo M (2006). Relative mobility of heavy metals from the discharge Akouédo and risk of groundwater contamination from Continental Terminal (Abidjan-Côte d'Ivoire). Afr. Sci. 02(1):39-56.

Lombi E, Zhao FJ, Dunham SJ, McGrath SP (2001). Phytoremediation of heavy metal-contaminated soils: natural hyperaccumulation versus chemically enhanced phytoextraction. J. Environ. Qual. 30:1919-1926.

Mahmud R, Inoue N, Kasajima SY, Shaheen R (2008). Assessment of potential indigenous plant species for the phytoremediation of Arsenic-contaminated areas of Bangladesh. Int. J. Phytorem. 10(2):119 -132.

Maiti RK, Pinero JLH, Oreja JAG, Santiago DL (2004). Plant based bioremediation and mechanisms of heavy metals tolerance of plants: a review. Proc. Indian Natl. Sci. B70(1):1-12.

Maurice C, Bergman A, Ecke H, Lagerkvista A (1995). Vegetation as a biological indicator for landfill gas emissions. Initial investigations. In: Proceedings of Sardinia 95, fifth International landfill symposium, St Margherita di pula S, Italy, 2-6 October.

McEldowney S, Hardman DJ, Waite S (1993). Treatment technologies. In: McEldowney S, Hardman DJ, Waite S, (eds.) Pollution, ecology and biotreatment. Longman Singapore Publishers Pvt. Ltd. Singapore.

Micieta K, Murin G (1998). Three species of genus Pinus suitable as bioindicators of polluted environments. Water Air Soil Poll. 104:413-422.

Miquel G (2001). Les effets des métaux lourds sur l'environnement et la santé. Rapport de l'office parlementaire d'évaluation des choix scientifiques et technologiques.
Mohamed AE, Rashed MN, Mofty A (2003). Assessment of essential and toxic elements in some kinds of vegetables. Ecotox. Environ. Safe. 55:251-260.
Moodley KG, Baijnath H, Southway-Ajulu FA, Maharaj S, Chetty SR (2007). Determination of Cr, Pb and Ni in water, sludge and plants from settling ponds of sewage treatment works. Water SA 33:723-728.
Mushrifah I, Razif A, Khairiah J, Tan KH, Ooi CC (2005). Uptake of Tin by *Cyperus rotundus* L. in pot experiments. Malays. Appl. Biol. 34(2):25-30.
Nagendra R, Selvam A, Kurian J, Chart C (2006). Phytoremediation and rehabilitation of municipal solid waste landfills and dumpsites: a brief review. Waste Manag. 26:1357-1369.
Pillay AE, Williams JR, Al-Lawati MO, Al-Haddabi SMH, Al-Hamdi MH, Al-Hamdi A (2003). Risk assessment of chromium, arsenic in dead palm leaves used as livestock feed. Environ. Int. 29:541-542.
Prabha KP, Loretta YL (2007). Phytoremediation technologies: hyperaccumulation metals in plants. Water Air Soil Poll. 184:105-126.
Prasad MNV (2001). Bioremediation potential of Amaranthaceae. In: Proceeding of the 6^{th} International in situ and on site bioremediation symposium, 4-7 juin, 2001, San Diego, California, USA.
Prasad MNV, Freitas HMO (2003). Metal hyperaccumulation in plants-Biodiversity prospecting for phytoremediation technology. Elect. J. Biotechnol. 6:285-321.
Prasad MNV (2004). Phytoremediation of metals in the environment for sustainable development. Proc. Indian Natl. Sci. Acad. B70(1):71-98.
Proctor J, Phillipps C, Duff GK, Heany A, Robertson FM (1989). Ecological studies in Gunung Silam, a small ultrabasic mountain in Sabah, Malaysia. Some forest processes. J. Ecol. 77:317-331.
Rajakaruna N, Bohm BA (2002). Serpentine and its vegetation: a preliminary study from Sri Lanka. J. Appl. Botany 76:20-28.
Raskin I, Kumar NPBA, Dushenkov S, Salt DE (1994). Bioconcentration of heavy metals by plants. Curr. Opin. Biotechnol. 5:285-290.
Reeves RD (2003). Tropical hyperaccumulators of metals and the potential for phytoextracation. Plant Soil 249:57-65.
Reeves RD, Baker AJM (2000). Metal accumulating plants. In: Raskin I, Ensley BD, eds. Phytoremediation of toxic metals: using plants to clean up the environment. New York, John Wiley and Sons Inc.
Salt DE, Smith RD, Raskin I (1998). Phytoremediation. Ann. Rev. Plant Physiol. Plant Mol. Biol. 49:643-668.
Sao V, Nakbanpote W, Thiravetyan P (2007). Cadmium accumulation by *Axonopus compressus* (Sw.) P. Beauv. and *Cyperus rotundus* L. growing in cadmium solution and cadmium-zinc contaminated soil. Songklanakarin J. Sci. Technol. 29(3):881-892.
Shams KM, Tichy G, Fischer A, Sage M, Peer T, Bashar A, Filip K (2009). Aspects of phytoremediation for chromium contaminated sites using common plants *Urtica dioica*, *Brassica napus* and *Zea mays*. Plant Soil 328(1-2):175-189.
Thangavel P, Subbhuraam CV. 2004. Phytoextraction: role of hyperaccumulators in metal contaminated soils. Proc. Indian Natl. Sci. Acad. B70(1):109-130.
Truong P (1994). *Vetiver grass*, its potential in the stabilization and rehabilitation of degraded and saline lands. Ed.V.R. Squire and A.T.Ayoub: Halophytes a resource for livestock and for rehabilitation of degraded land. Kluwer Academics Publisher, Netherlands.
Wei S, Zhou Q (2008). Screen of chinese weed species for cadmium tolerance and accumulation characteristics. Int. J. Phytorem. 10:584-597.
Xiong ZT (1998). Lead uptake and effects on seed germination and plant growth in a Pb hyperaccumulator *Brassica pekinensis* Rupr. Bull. Environ. Contam. Toxicol. 60:285-291.