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Assessment of metal pollution in soil and in vegetation near the wild garbage dumps at Mostaganem region

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Abstract

Within the scope of protection of the environment, and with particular aim the normalization of landfill sites, this study examines soil pollution and natural vegetation of the three sites near three major Wild discharges in the region of Mostaganem (western Algeria). The contamination of both soil and vegetation was evaluated by assaying the major metallic elements (K, Na, Ca, Al, Fe, Mg, Si, Mn) and heavy metals (Cr, Zn, Cu, Cd, Ni, Pb, As, Co). This work reveals significant contamination of the sites studied and it emphasized a large variation in concentration depending on the element analyzed and the study site. The pollution index of soil is generally very high (7.56 for SI, 7.32 to 7.84 for SII and SIII). The transfer factor (TF) of heavy metals in luxurious growing species was calculated, it reveals a bioaccumulation of metals, which varies according to plant species and nature of metals. The hyper accumulation (TF > 1) was registered for Ni, Cr, Cu, Zn in *Euphorbia cyparissias* L (1.82); *Asparagus officinalis* L (4.38); *Marrubium vulgare* L (8.08) and *Pistacia lentiscus* L (9.14) respectively. The accumulation was observed according to TF values below 1 for Cd, Pb, As and Co, in *Euphorbia cyparissias* L (0.27 for Cd); *Marrubium vulgare* L (0.27 for Pb); *Asparagus officinalis* L (0.75 for As) and *Pistacia lentiscus* L (0.44 for Co).

Key words: Dump; Metallic pollutant; Contamination; Soil; Vegetation.

Introduction

Human activities as well as modern civilization produce large masses of solid and liquid waste from various sources: domestic, industrial and hospital waste. These wastes are often harmful because of their bulky or unsightly; they can also be toxic and cause serious pollution problems.

In Algeria, pollution, deterioration of life and damage to ecosystems are tangible realities. There are about 3000 illegal dumps on the Algerian territory, usually located on agricultural land, or livestock or along lakes and rivers.

More than 2 million tons of hazardous industrial waste is currently stored of which 55% is stored in the Eastern region, 26% in the Western region and 19% in the central region of Algeria [1]. It should be noted that more than 80% of waste is not treated or recycled. Consequently, expansion of illegal dumps around the country is increasing. Waste is generated continuously with an increasing amount; waste are heterogeneous .Their quantitative and qualitative composition varies according to geographical factors, climatic, economic, racial, social and demographic [2].

Located in the western region of Algeria, Mostaganem has a large number of landfills where there are 20 wild dumps, including three classified as the most important. They are named: dump of El Hchem, dump of Ain-tedless and dump of Hassi Mameche located in the North East, North West and North West respectively. These dumps represent a favorable medium for the multiplication of transmission vectors of diseases, such as arthropods (flies and mosquitoes), rodents (leptospirosis carriers, typhus, trichinosis) [3]. Hence they present a microbiological danger, because the waste contains all pathogenic microorganisms (bacteria, virus, fungus, yeast).

The Wild dumps constitute a source of chemical contamination, particularly heavy metal contamination. After the rain and natural fermentation of waste, they produce a fluid fraction named lixiviate rich on mineral and organic pollutants [4, 5].
The incineration of waste produces gaseous pollutants which contain heavy metals [6]. The metal pollutants accumulated in soil and under some biogeochemical conditions may pass in the soil solution [7], and consequently become bio-available and absorbed by plants [8].
With high concentration of pollutants, the pollution of dumps affects plant growth by changing the biodiversity of vegetation because the sensitive plants to heavy metal stress are not able to survive. The plants, which survive the high amount of heavy metals, provide its descendants [9]. During a long time of exposure to polluted medium, the plants adapt to this situation with tolerant high amount of heavy metals by many mechanism and pathways such as: adsorption, detoxification, immobilization and accumulation.
The dumps of domestic waste, industrial or other, deserve special attention, because they are potential sources of significant pollution including contamination by heavy metals that have a high ecotoxicity; and they could be involved in many diseases with central nervous system, liver kidney, but also cancer and embryonic malformations [10,11].

2. Materials and methods

2.1. Presentation of the study area

Our study was conducted in three wild landfills at Mostaganem (North West Algeria). These three dumpsites are considered the largest among the 20 existing ones. These landfills are located in the vicinity of agricultural land and housings. The three sites are named: dumpsite of El-Hchem, dumpsite of Hassi-Mameche and dumpsite of Ain- Tedless (Table 1).

Table 1: Geographical and topographical characteristics of landfills

Dump site	area (ha)	Topography	Daily tonnage (T/day)
El-Hchem (Site I)	02.5	Rugged plateau, Slopes to the south west	33.8
Hassi Mameche (Site II)	03.2	Land slightly flat (low slope west)	15.2
Ain-tedless (Site III)	06.2	Flat soil	82

2.2. Physical analysis of soil

The determination of particle size (% sand, % clay and % silt) and the measurement of pH and organic matter were conducted with referring to the works of Pétard J. (1993) [12]

2.3. Metal analysis in soil and vegetation

For each site 4 soil samples were collected at 50 meters from the landfills center in for directions: North, East, West and South. The soil samples were mixed, air dried and sieved (<2 mm) and then ground (<180 microns).
For vegetation, only roots and leaves of plant were collected. After rinsing with water tap and distilled water, roots and leaves were dried in oven at 70°C during 48 h and the dry matter was homogenized. To mineralize samples, 2 mL of sulfuric acid (H2SO4), 6 mL of nitric acid (HNO3) and 6ml of oxygenized water (H2O2) were added to 0.5g of homogenized soil and 0.5g of dried and pounded vegetal matter [13]. This mixture is heated during 30min. The residue is cooled and filtered then a 25ml of nitric acid is added. The analyses of “mineralisate” is realized by metallic “dosage” in the obtained solution by using introductive coupled plasma spectrometry (JOBIN-YVON 70 ICP).

3. Results and discussion

3.1. Soil characteristics

Table 2 presents the relative changes of soil characteristics near landfills among the different sites. The pH values varying between 8.11, 8.18 and 8.20 in sites SII, SIII, and SI respectively.
All The soils have a sandy-loam texture with 58.20% of coarse sand 17.80% of fine sand, 12.63 % clay and 10.62% of silt for the site I; 50.66, 19.97, 13.08 and 16.35% respectively for the site II and 50.20, 23.80, 13.58 and 12.40% for the site III. The organic matter in soils presents 1.98, 2.43, and 2.48% respectively for the sites I, II and III.

3.2. Contents of major metallic elements in the soil

Table 3 illustrates the major mineral elements contents in soils at 10 to 40 cm of depth. We note that site III records the high concentration of Aluminum (Al) and Magnesium (Mg) (3095 $mg.Kg^{-1}$ and 4127 $mg.Kg^{-1}$ respectively). The average quantities of Potassium (K), Calcium (Ca), Sodium (Na) and Iron (Fe) are as important in Site III (1269 $mg.Kg^{-1}$, 4523 $mg.Kg^{-1}$, 1260 $mg.Kg^{-1}$ and 8539 $mg.Kg^{-1}$ respectively). Silicium (Si) and Manganese (Mn) are smaller compared to all others elements (147 $mg.Kg^{-1}$ and 155 $mg.Kg^{-1}$respectively).

Table 2: Soil characteristics near the dumps (Soil depth 10 to 40 cm)

Soils	pH	OM %	Clay %	Silt %	coarse sand %	Fine sand %
Site I	8.20	1.98	12.63	10.62	58.20	17.80
Site II	8.11	2.43	13.08	16.35	50.66	19.97
Site III	8.18	2.48	13.58	12.40	50.20	23.80

Table3: Major metals (mineral elements) in soil samples near the dumps ($mg.Kg^{-1}$)

Soils	K	Ca	Mg	Si	Al	Fe	Na	Mn
S(I)	1062±11.3	4133±18.3	3122±10.3	139±11.2	2595±55.8	7519±39	1168±43.4	149±4.3
S(II)	1223±20.2	4213±17.2	4018±11.4	143±13.6	2965±61.3	8521±41	1234±56	150±5.2
S(III)	1269±21.3	4523±21	4127±11.8	147±14.4	3095±75.8	8539±49	1260±60.4	155±7

S(I): Site (I); S(II): Site (III) and S(III): Site(III)

3.3. Levels of heavy metals in the soil

As shown in table 4, Chromium (Cr), copper (Cu), zinc (Zn), nickel (Ni), lead (Pb), Cadmium (Cd), arsenic (As), and cobalt (Co) are relevant heavy metals analyzed in soil of the three landfills. Metal mean contents range from 1389 $mg.Kg^{-1}$ (Site II) to 1558 $mg.Kg^{-1}$ (Site III) for **Cr**, from 1002 $mg.Kg^{-1}$ (Site III) to 1085$mg.Kg^{-1}$ (Site I) for **Zn**, from 445 $mg.Kg^{-1}$ (Site II) to 502 $mg.Kg^{-1}$ (Site III) for **Cu**, from 130 $mg.Kg^{-1}$(Site I) to 159$mg.Kg^{-1}$ (Site III) for **Co**, from 100 $mg.Kg^{-1}$ (Site I) to 105.2 $mg.Kg^{-1}$ (Site III) for **Pb**, from 95$mg.Kg^{-1}$ (Site II) to 100 $mg.Kg^{-1}$ (Site III) for **Cd**, from 28 $mg.Kg^{-1}$ (Site II) to 33 $mg.Kg^{-1}$ (Site I) for **Ni** and from 12 $mg.Kg^{-1}$ (Site III) to 16 $mg.Kg^{-1}$ (Site II) for **As**

Table 4: Heavy metals in soil samples ($mg.Kg^{-1}$) and pollution index **PI** near the dumps

Sols	Cr	Ni	Cu	Zn	Cd	Pb	As	Co	PI
S(I)	1435±16.1	33±4.1	500±30.2	1085±74.4	98±2.3	100±3.2	13±0.7	130±1.3	7.56
S(II)	1389±12.5	28±2.3	445±28	1015±70.2	95±0.9	103±1.2	16±0.4	140±2.8	7.32
S(III)	1558±22.8	32±4.4	502±37.6	1002±9.8	100±5	105.2±7	12±1.27	159±6.5	7.84

3.4. Pollution Index of heavy metals in soils (PI)

This index is calculated by the ratio of metal concentrations in the soil based on the corresponding values suggested by Kloke (1979 standards) [14] and which correspond to tolerable levels in the soil: **PI**= **[(**Cd/3 + Cr/100 + Cu/100 + Pb/100 + Zn/300 + Co/50 + Ni/50 + as/20)] /8

The critical heavy metal concentration in the soil is defined as the value above which toxicity is possible. As reported in literature [15]; these values represent the concentration of 8 ppm for Cd, 125 ppm for Cu and 400 ppm for Pb and Zn. Obtained results show that metal concentrations are above the critical level in the three studied sites for at least three of these metal elements.

The pollution index (**PI**) is a criterium for assessing the toxicity of a soil. It identifies a phased array type contamination in samples [16]. In this study, the pollution index was calculated for the different sampling sites and reported in Table 4.The three sites I, II and III have pollution index greater than 1 and represent respectively 7.56**,** 7.32, and 7.84. The soils landfill site of Ain -Tedless is the more contaminated one than the others.

Soils near landfills are rich in major mineral elements (K, Na, Ca, Al, Fe, Mg, Si, Mn) and are largely polluted with heavy metals (Cr, Zn, Cu, Cd, Ni, Pb, As, Co), and the calculated IP exceed largely the value of 1. The texture of soils is sandy soil, and the exchange capacity of these soils is weak. The amount of clay in the three sites SI, SII, SIII is slight: 12.63, 13.08 and 13.58% respectively. The presence of high quantities of sand 58% and small quantities of clay in soil facilitate the metal infiltration to the soil depth and will be contaminate the groundwater, [17-19].

The variation of quantities of major elements in the three sites is probably related to the difference of soil nature (pedogenesis) [20, 21].

The presence of heavy metals, in soils near the dumps, is related to the nature of garbage rejected. Quantities of heavy metals found are important and exceed largely the maximum amounts authorized by WHO (Cr: 150

mg.Kg^{-1}, Zn: 300 mg.Kg^{-1}, Cu: 100 mg.Kg-1, Co: 30 mg.Kg^{-1}, Pb: 100 mg.Kg^{-1} and Cd: 0.7 mg.Kg^{-1}) [22]. As cited in literature, some contaminations were observed in many dumps towards the world: Akouédo in Abidjan [19], Mall in New Jersey [23] and Sidney [24].

3.5. *Concentrations of major metals and heavy metals in plants growing near the dumps*

The presence of metallic elements such as excessive levels of heavy metals in soil significantly changes the floristic composition of sites. The presence of vegetation species in their sites means that species supports excessive levels of metals and are tolerant to heavy metals.

The floristic population analysis shoes that number of plant species present near the landfills are reduced. The botanic study of plants reveals the presence of 22 plant species and 17 families. Among these plant species met, only 7 plant species that have an important development and grow were selected to analyze metals in their tissues. These plant species are: *Pistacia lentiscus* L; *Euphorbia cyparissias L; Marrubium vulgare* L; *Asparagus officinalis* L; *Malva sylvestris* L; *Plantago lanceolata* L and *Urtica dioica* L. These plant species are dominant in the three sites studied (Table 5).

Table 5. Nature of vegetal species near the dumps

Family	species	Distribution
Aizoaceae	*Mesembryanthemum crystallinum* L	Herb (SI)
Anacardiaceae	*Pistacia lentiscus* L *****	Herb (S II,III)
Apiaceae	*Daucus carota L*	Herb (S II,III)
Arecaceae	*Chamaerops humilis* L	Herb (S I **)**
Asteraceae	*Scolymus hispanicus* L	Herb (S III,III)
	Centauria cyanus L	Herb (SI, II, III)
Brassicaceae	*Sinapis arvensis* L	Herb (SI, II,III)
Chenopodiaceae	Chenopodium bonus-henricus L	Herb (SI, II,III)
Euphorbiaceae	*Euphorbia cyparissias* L *****	Herb(S III)
Fabaceae	*Retama monosperma* L	Herb (SII,III)
Lamiaceae	*Lavendula stoechas* L	Herb (SII,III)
	Lavendula dentata L	Herb (SI, II, III)
	Marrubium vulgare L *****	Herb (SI, II, III)
Liliaceae	*Asparagus officinalis* L *****	Herb (SI, II, III)
Malvaceae	*Malva sylvestris* L *****	Herb (SI, II, III)
Oleaceae	Olea europea L	Shr (S III)
Plantaginaceae	*Plantago lanceolata* L *****	Herb (SI, II,III)
Rosaceae	*Malus sylvestris* L	Herb(SIII)
Poaceae	*Hordeum murinum* L	Herb (SI, II,III)
	Arundo donax L	Herb (SII,I) Herb
Urticaceae	*Urtica dioica* L *****	(SI, II,III)
	Urtica urens L	Herb (SI, II,III)

Shr: Shrub, Herb: Herbaceous, S: Site *: Plant species studied

The major elements content in the plant are presented in table 6. Results show that the values of K, Ca, and Na elements are adequate as in plant growing in natural soil. The values of Mg and Fe met in *P. lentiscus* L (3806 mg/kg^{-1} Fe) and *Urtica dioica* L (7544 mg.Kg^{-1} Mg) exceed the natural values described by [25]. The values of Al and Si exceed the natural values in all plant species grown in all landfills. However values of Mn met in *P. lentiscus* Land in *A. officinalis* L (14 mg.Kg-1 and 38mg.Kg^{-1} respectively) are lower than natural values in plant species grown on natural soil (200 mg.Kg^{-1}) [25]. About the contamination of spontaneous plant by heavy metals in dumps, few studies were done. Results show that contents of heavy metals (Cr, Cu, Zn, Co, Pb, Ni, Cd and As) in plant tissues are very high. Maximum of heavy metals values met respectively in plants are 9168.6 mg.Kg^{-1} in *P. lentiscus* L for Zn, 6829 mg.Kg^{-1} in *A. officinalis* L for Cr, 4030.6 mg.Kg^{-1} in *M. vulgare* L for Cu, 71mg.Kg^{-1} in *P. lentiscus* L for Co, 57.8mg.Kg^{-1} in *E. cyparissias* L for Ni, 28.6 mg.Kg^{-1} in *M .vulgare* L for Pb, 28.2 mg.Kg^{-1} in *E. cyparissias* L for Cd and 9 mg.Kg^{-1} in *A. officinalis* L for As (Table 7).

In our results, the quantities of major elements found in the plants are adequate according to those described by Gobat A.M. [25]. Except Fe and Mg that exceed the natural values in *P. lentiscus* L and *U. dioica* L. Quantities of Al and Si found in all the plants studied exceed largely the natural amount in plant this explains why these plants tolerate and accumulate these metals.

Quantities of metals (Cr, Cu, Zn, Co, Pb, Ni, Cd and As) found in plant tissues exceed those recommended by WHO [23]. The plants studied in our work are able to absorb a large quantity of these metals and transfer them in their leaves.

Table 6: Major metals (mineral elements) contents in tissues of spontaneous vegetal species (mg.Kg^{-1}).

Vegetal species	K	Ca	Mg	Si	AL	Fe	Na	Mn
P. lentiscus L	9654 ± 42	7414 ± 29	186 ±18	167±14.4	71 ± 6.5	3806 ±46	1710± 23	14 ±2.2
E.cyparissias L	3645 ± 21	6162 ± 26	1083±13	154 ±11.2	82 ± 3.4	1560 ±30	3165± 53	29 ±2.1
M .vulgare L	3942 ± 24	5156 ± 4	3439± 49	196 ±10.3	290 ±12.3	1833 ±17.1	3624 ±17	34 ±5.4
A. officinalis L	20003 ± 63	6981 ± 30	2569±7	164 ±2.2	298 ± 50	1581 ±40.9	4977± 91	38 ±2.7
M. sylvestris L	30154 ± 29	6235 ± 21	6342±19	123 ±1.7	65 ±1.6	340 ±13	3764 ±24	31 ±1.4
P. lanceolata L	1955 ± 45	5447 ±28	391 ±10	196 ± 20	170 ± 24.7	438 ± 35.6	3612 ± 23	22 ±4.4
U. dioica L	35158 ± 38	5266 ±17	7544±22	222 ± 8.3	146 ±14.4	750 ± 8.6	5538 ± 25	33 ±2.7

Table 7: Heavy metals contents in tissues of spontaneous vegetal species (mg.Kg^{-1}).

Vegetal species	Cr	Ni	Cu	Zn	Cd	Pb	As	Co
P. lentiscus L	3556 ± 35.2	13.6 ± 2.1	1535 ±49	9168.5 ± 6	0.1 ± 0	19.4 ± 2.6	0.1 ± 0	71 ±10
E.cyparissias L	623 ± 5 .8	57.8 ± 3.2	710 ±12	886 ± 0.10	28.2 ±1.3	22 ± 3.5	1.8 ±0.45	30.2 ± 3.9
M .vulgare L	755 ± 14. 5	0.18 ±0.03	4030 ± 9	1919 ± 8.2	5.6 ± 0.5	28.6 ± 2.1	6 ± 2.2	62.4 ± 6.0
A. officinalis L	6829 ± 29.4	0.1± 0	1664 ± 33	3201.6 14.8	0.14 ±0.04	15 ± 0 .1	9 ±2.23	24 ± 8.2
M. sylvestris L	1007.4 ±11.4	41.6 ± 3.1	429 ± 29	795 ± 8.4	10.9 ±4.6	16 .2 ±0.5	3.14±0.34	38.6 ±3.9
P. lanceolata L	940 ± 32.4	27 ± 5.7	566 ± 14	864 ± 31.5	16 ± 1.4	13 ± 2.7	0.1 ± 0	8 ± 4.4
U. dioica L	1348 ± 17.8	0.1± 0	153 ±9	438 ± 14.8	5 ± 0	16 ± 0.8	6 ± 2.2	27 ± 2.7

The calculation of Transfer Factor **TF** (Table 8) showed that the plants unlike accumulate metals. The finding hyperaccumulator plants with TF>1 are: *Asparagus officinalis* (4.38) and *Pistacia lentiscus* (2.26) for Cr; *Euphorbia cyparissias* (1.82) and *Malva sylvestris* (1.29) for Ni; *Marrubium vulgare* (8.08), *Asparagus officinalis* (3.31), *Pistacia lentiscus* (3.06) and *Euphorbia cyparissias* (1.42) for Cu; *Pistacia lentiscus* (9.14), *Asparagus officinalis* (3.19) and *Marrubium vulgare* (1.91) for Zn.
The accumulator plants that TF < 1 for Cd, Pb, As and Co, are *Euphorbia cyparissias* (0.27), *Plantago lanceolata* (0.15) for Cd; *Marrubium vulgare* (0.27), *Euphorbia cyparissias (*0.20) for Pb; *Asparagus officinalis* (0.75), *Urtica dioica* (0.5) for As and *Pistacia lentiscus* (0.44), *Marrubium vulgare* (0.38) for Co.

Table 8: Transfer factor (**TF**) of heavy metals in spontaneous vegetal species

Vegetal species	Transfer factor (**TF**)							
	Pb	As	Co	Cd	Zn	Cu	Ni	Cr
M.vulgare L	0.27a	0.502b	0 .39b	0.052d	1.91c	8.08a	0.005e	0.48e
P. lanceolata L	0.12d	0.008d	0.05e	0.156b	0.86d	1.12c d	0.85c	0.59d
U. dioica L	0.15cd	0.5b	0.16d	0.043d	0.43e	0.303e	0.003e	0.86c
A.officinalis L	0.14d	0.75a	0.14d	0.001e	3.19b	3.31b	0.003e	4.38a
P.lentiscus L	0.18bc	0.008d	0.44a	0.001e	9 .14a	3.06b	0.43d	2.27b
E.cyparissias L	0.2b	0.146cd	0.19d	0.271a	0.864d	1.42c	1.82a	0.39f
M. sylvestris L	0.15cd	0 .26c	0 .24c	0.104c	0.79d	0.85d	1.29b	0.64d

TF = value of the metal in the plant / value of the same metal in the soil [26].
Transfer of heavy metals from the soil to the plant is highly significant between species (P <0.05) for the eight metals analyzed,
a , b, c, d, e = homogeneous groups.

Conclusion

Our study showed the impact of landfills on environmental pollution and the transfer through plants that could bring harm to human health when the metal pollutants will enter the food chain. The concentrations of metallic elements: Cr Cu, Zn, Pb, Ni, Cd, Co, As, analyzed in soils and vegetation exceed largely the critical thresholds set by WHO. This pollution varies according to type of terrain and nature of pollutants. Site Ain Tedless dumps is more polluted than the other sites. All the plants studied are metal accumulators, some plants are hyper accumulators such as *A .officinalis, P.lentiscus* (Cr); *E cyparissias, M. sylvestris* (Ni) ; *M. vulgare, A. officinalis , P. lentiscus, E. cyparissias* (Cu) and *P. lentiscus , A. officinalis, M. vulgar*e (Zn).

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