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Phytoremediation of soil Contaminated by Heavy Metals within a Technical Landfill Center Vicinity: Algerian Case Study

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ABSTRACT: The contamination of environment with heavy metals has become a serious problem which can affect the human health. Three heavy metals (Zn, Cd and Pb) were determined in soil and plants for below and aboveground parts along landfill Demina center, located in the wilaya of Jijel, Algeria to evaluate their behavior and uptake by *Ditrichia viscosa*, *Juncus effusus* and *Solanum nigrum*. In our research we tried to study the capacity of these spontaneous plants to accumulate and to translocate heavy metals from soil to their tissues during three years. The heavy metals examined in the soils of the study area showed variations in concentrations, the study area may be practically unpolluted with Zn and Pb (CF; 0.45 and 0.98 successively) and very contaminated with Cd (CF; 8.53). According to the results obtained, the soil is uncontaminated with lead (Igeo=-0.60) and zinc (Igeo= -1.42) but it is heavily contaminated with cadmium (Igeo=2.5) along the study area. Overall the BCFS (bioconcentration factors) are superior to 1, for the all heavy metals and species. However, BCFs follow the following order; $BCF_{Zn}>BCF_{Pb}>BCF_{Cd}$ for *Ditrichia viscosa*, the following order $BCF_{Pb}>BCF_{Zn}>BCF_{Cd}$ for *Juncus effuses* and follow the following order; $BCF_{Zn}>BCF_{Cd}>BCF_{Pb}$ for *Solanum nigrum*. The TFs (translocation factor) of the present study showed that *Solanum nigrum* can translocate the three of the metals into their aboveground parts.

Keywords: *Ditrichia viscosa*, *Solanum nigrum*, *Juncus effusus*, bioconcentration factor, contamination factor, geoaccumulation factor.

INTRODUCTION

The main sources of environmental contamination by heavy metals in addition to landfills and waste disposal on land are human activities such as energy production, agricultural fertilizers, domestic sewage and industries (Ross., 1994; Chehregani et al., 2009; Bialowiec et al., 2010; Zovko et al., 2011; Singh et al., 2015). Heavy metals are little or not at all degradable and tend to bioaccumulate in the environment (Tabat, 2001). Because they are not readily metabolized or excreted, this means that they become more highly concentrated as they move up the food chain (Konkolewska et al., 2020). Soil contamination by heavy metals is widely studied (Tabat, 2001; Chehregani et al., 2009; Zovko et al., 2011; Singh et al., 2015; Feranadez et al ., 2016). Several methods have been undertaken to remove heavy metals from contaminated soil, but phytoremediation has a singularity

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compared to physicochemical and mechanical remediation methods (Tong et al., 2004).

The generic term “phytoremediation” consists of the Greek prefix phyto (plant), attached to the Latin word remedium (to correct or remove an evil) (Centofanti., 2014), this technique includes a range of plant-based remediation processes such as phytoextraction, phytostabilization, phytoimmobilization, rhizofiltration and phytovolatilization (Heavy metals contamination., 2000), increased attention is being paid to phytoextraction (Rebele et Lehman., 2011; Feranadez et al ., 2016), which is the technology that uses plants to extract elements from polluted or mineralized soils, and accumulate them in harvestable organs and tissues in order to remove the pollutants/contaminants from the field (Srilakshmisumitha et al ., 2013; Irfan Dar et al ., 2015) such as soil and water.

Surveying natural vegetation in a contaminated environment is an effective approach to identify plants with high bioaccumulation potential and their ability to accumulate toxic metals in their tissues (Fernández et al. 2017). Hyper accumulators are the plants who are able to accumulate unusually high levels of heavy metals in their aboveground harvestable parts for example: >100 mg Cd kg^{-1}, >1000 mg Cu, Ni, and Pb kg^{-1}, and >10,000 mg Zn kg^{-1} in the dry matter (dm) of shoots when growing in their natural habitats (Khan et al ., 1999; Minlim et al ., 2004; Zhuang et al., 2007; Veratomé et al ., 2008; Kyu Kwon et al., 2015). To date, approximately 400 plant taxa worldwide from at least 45 plant families have been reported to hyperaccumulate metals **(**koopmans et al ., 2008), *Thlaspi, Urtica, Chenopodium, Polygonum sachalase, Alyssim, Zea mays, Pisum sativum, Avena sativa, Hordeum vulgare and Brassica juncea,* are the most mentioned in the recent data (Khan et al., 2016).

The most common means used to manage municipal solid waste (MSW) collected are disposed of in landfills worldwide (Swati et al., 2014), and landfilling is the principal method used to remove and disposal major MSW in modern cities (Wong et al., 2015). Landfills were thought to be the safe disposal method of MSW (Adamcová et al., 2016). Heavy metals pollution and mobility in soils within landfill vicinity is widely studied worldwide (Mikac et al., 1998; Admacova et al., 2016; Vaverková et al, 2017; Nykia et al., 2019), and in Algeria (Belabed, et al., 2014; Foufou et al., 2017; Belabed, 2018; Mouhoun-Chouaki et al., 2019; Sahnoune and Moussaceb, 2019).

Algeria launches a project to build 122 Technical Landfill Centers (TLC class 2) and 146 controlled landfills (74 TLCs are operational put into service) (Centre National des Technologies de Production plus Propre, CNTPP, Algeria, 2015). In Algeria landfilling is the most frequently used method for the disposal of urban wastes (both non-hazardous and hazardous wastes). Demina (TLC), located near Taher city (Jijel, Algeria), constitutes one of the three technical landfills of Jijel province is a case of landfilling of waste onto permeable alluvial sediment without any protected barrier. It has a greatest impact on local residents; it contributes to the release of odors, dust and insects, in addition to contaminated water and leachate are directly drained into Boulkeraa watercourse without any prior treatment, which constitutes a threat to the environment. However we note that Boulkeraa River is the main source of irrigation in the region. To our knowledge, this is the first study carried out on the environmental impact of TLCs in the wilaya of Jijel.

Following the previous considerations, the main objectives of this investigation were;

1. To quantify the concentration levels of heavy metals (Pb, Zn and Cd) in Demina’s technical landfill center soils;

2. To characterize the plant species able to germinate spontaneously and to survive on contaminated soils. For this, three species plants namely *Ditrichia viscosa*, *Juncus effusus* and *Solanum nigrum* were identified, sampled and analyzed with the aim to evaluate their potential use in phytostabilization or phytoextraction trials for recovering areas affected by heavy metals;
3. To evaluate the accumulation potential of the three species growing on the contaminated site;
4. To determine the mobility of the heavy metals in the soil.

MATERIALS AND METHODS

The research was conducted in technical landfill center of Demina, (36° 43` 41.03`` N, 5° 54` 59 .90`` E, coordinates were determined by global positioning system, GPS), in Taher city (Fig.1). The city covers more than 350 km^2 and has an urban population of approximately 147 61. It is located north-east of Algeria of about 4,05 Km from the National road n°142.The site covers approximately 4 hectares. It enjoys an essentially Mediterranean climate with mild, relatively wet winters and dry, hot summers, the average annual rainfall is about 541mm with a maximum of 1407.9 mm; with an average temperature varies between 11.23 and 25.13°C (National weather office). The main water sources are; precipitation and groundwater. Contaminated water and leachate are directly drained into Boulkeraa watercourse without any prior treatment. According to center officials, the landfill receives wastes from five urban agglomerations, Taher, Chahna, Chekfa, Kennar, Oudjana and Emir Abdelkader. It receives between 20 and 25 tons of waste per day.

A total of 81 composed samples were collected from the study area (of 0-15 cm depth), they returned to the laboratory, dried and crushed into powder and sieving trough 2 mm.

The physical and chemical soil properties including pH, EC, CEC, OM and total limestone were determined following the method mentioned by (Clement et al ., 2003).

According to Hoening et al, 2012, total heavy metals concentrations were quantified after acidic digestion with concentrated HCl (37%), HNO_3 (65%); at the ratio of 3:1(v/v), the solution was boiled on a hot plate, let it cool down a bit , afterwards add 50 ml of deionized water. The measure of Pb, Cd and Zn concentrations was realized by a flame atomic absorption spectroscopy (FAAS).

The plant harvest was carried out during the winter of 2014, 2015 and 2016. Samples were rinsed with distilled water to remove surface dust and soil particles, each sample was separated into two parts (roots and aboveground parts), dried at 40°C to constant weight, grounded into fine powder and sieved at 2 mm. Acid digestion of plant samples was performed using a mixture of concentrate HNO_3, H_2O_2 (30%) and the sulfuric acid, after cooling in the room temperature, the residue was diluted with dionized water to 50 ml, the plant extracts were analyzed by the FAAS (Hoening and al .,2012)

Bioconcentration is the increasing in the concentration of the pollutant during its direct passage from the biotope to the organism; its assessment is based on bioconcentration data measured in the plant species studied. In land plants, this process takes place by the passage of soil pollutants to the plant through the root system. These processes can be expressed by using the concentration factor (FC), the bioconentration factor (BCF) or the bioaccumulation coefficient (BAC). BCF indicates the efficiency of a plant species in accumulating a metal into its tissues from the surrounding environment, which can be expressed as the ratio of the metal concentration within plant roots (mg.kg^{-1}) over that in soil/substrate.

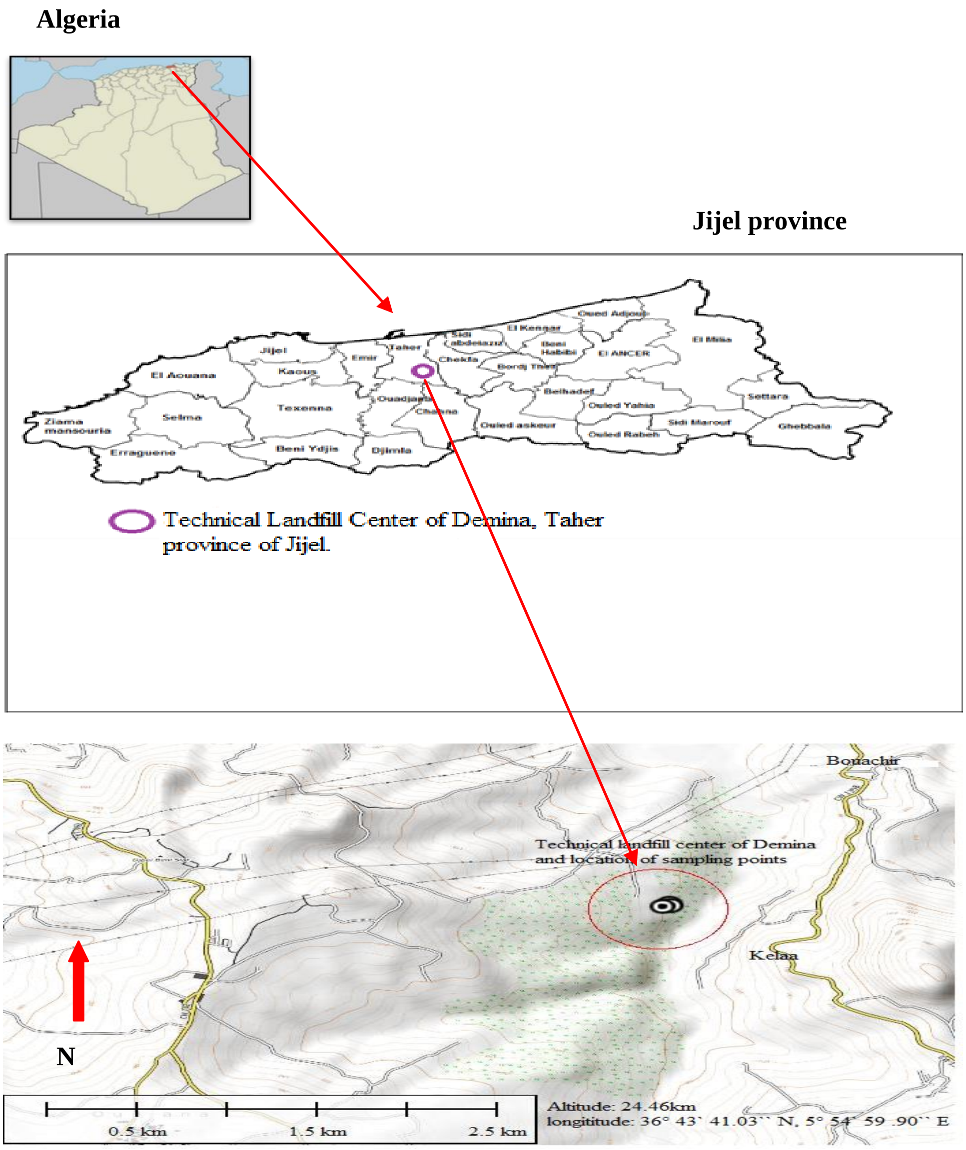

Fig. 1. the map of the study area and sampling location points of soil and plants. (Source: Global Mappper 20)

In our study, the bioaccumulation coefficient (BCF), is the ratio of the total metal concentration in the whole plant (root, stem and leaves) over that in the soil samples, they were calculated according to the following equation:

$$BCF = \frac{metal\ concentration\ in\ plants}{metal\ concentration\ in\ soil\left(or\ the\ substrate\right)}$$

(Sekabira et al., 2011).

TF, indicates the efficiency of the plant in the translocation of the accumulated metal from its roots to shoots or aboveground parts of the plant, was calculated as the ratio of the concentration of metal in the shoot to the metal concentration in roots.

TF= metal concentration in shoot tissue or aboveground parts (ppm or mg.kg^{-1})/metal concentration in root tissue (ppm or mg.kg^{-1}) (Rana et al., 2018; Wang et al., 2018; Thongchai et al., 2019; Liu et al., 2019; Ramanlal et al .,2020).

$TF=Me_{shoot}/Me_{root}$

The contamination factor (CF) is an assessment of sediment contamination by comparison of concentration with those of background sediments. It is used to assess the level of the contamination of the given metal in a soil and it is calculated according to the following equation:

$CF = C_{\text{metak in soil}} / C_{\text{metal background}}$ (Waheshi et al, 2017)

where $C_{\text{metal in soil}}$ is the mean content of the substance. The value should be given in ppm, and $C_{\text{metal background:}}$ is the reference value of the substance. The contamination factor (CF) represents the contamination of isolated elements.

In the soil if $C_{\text{metal in soil}} > C_{\text{metal background}}$ we can define the substance as contaminating or enriched, on the contrary if $C_{\text{metal in soil}} < C_{\text{metal background}}$, (Waheshi et al, 2017) then the element should not be characterized as contaminating in this context. It's very difficult to establish $C_{\text{métal background}}$ values for the sediments/soil of some studied areas, as a reference. So, in our work $C_{\text{métal background}}$ value (references point) has been taken according to Turekian et al. (1961).

The Igeo compares the measured concentration of the element in the fine-grained sediment fraction (C) with geochemical background value (B) in fossil clay and silt sediments.

The geoaccumulation factor (Igeo) was calculated to refer the level of the anthropogenic contamination in the soil or the substrate, and it is obtained by the following equation:

$Igeo = \log_2 [C_{\text{metal in soil}}] / 1.5 * [B_{\text{metal background}}]$

where 1.5 is correction factor of the background changes resulting of lithogenic effects (Förstner et al., 1993; Aydi, 2015; Waheshi et al, 2017).

Before each analysis we ensured that the materials were washed with the dimineralized water, to ensure the quality we replicated samples for both soil and plants, The calibrate of FAAS was doing after reading of each plant and after each reading soil samples using blank and we achieve a calibration coefficient of r=0.99.

The analytical precision of the three duplicate sediment sample analyses of the metals was calculated as the average of the relative standard deviation of duplicate measurements. Station effect, species effect and year of sampling effect were determined using two way analysis variance (ANOVA) test using R language package version 3.0.2, the least significant difference was used for multiple comparison at $p<0.05$ level between metal concentration in area soil and metal content in plant tissue. Given that there was no significant ($P > 0.05$) difference in plant metal concentrations and for metals in soils.

RESULTS AND DISCUSSION

Results of physico-chemical parameters are reported in Table 1, where the values are expressed as the mean (of the three year of sampling (2014, 2015 and 2016) ± S.D.

In fact, the observations were made at three stations in the affected area. Acidity in technical landfill center of Demina soils ranged between pH 8.19 and 8.21 pH (mean 8.20). EC ranged from 240.74 to 240.7µs/cm (mean 255.93µs/cm), OM ranged between 4.87 and 5.42 % (mean 5.38), CEC ranged from 36.85 to 38.98 ms/eq and total limestone exhibited considerable variation, it was ranging between 2.65 and 6.47. The station 3 had maximum EC and OM values with 270.74µs/cm and 5.85 % respectively. Cation exchange capacity values were similar in all stations with a maximum of 38.98 (meq/100g) recorded in the first station and a minimum of 36.85(meq/100g) in station 3. As shown in table 1, total concentrations of Pb in the soil samples were ringing from 15.43 mg/kg in station 2 to 19.01 mg/kg in station 1, while that of Zn ranged from 38/53 mg/kg to 45/41 $mg.kg^{-1}$, these values were lower than the maximum permissible levels of metals given on soil guidelines (100mg/kg). Concentrations of Cd in soil samples ranged from 1/57 mg.kg^{-1} in the first station to 2/61 mg/kg in the third station, the levels of Cd were higher than recommended concentrations for uncontaminated soil which is 0.5 mg/kg (Weldegebriel et al., 2012).The concentrations followed the decreasing trend Zn>Pb>Cd. The Pb and Cd concentrations were statistically different between the three stations (2-way ANOVA; $P<0.05$) ($p=0.03$ for Pb and $p=0.02$ for Cd). No significant differences were observed between Zn concentrations in soil of the three stations ($p>0.05$).

Table 1. Physico-chemical properties and average metal concentration (mg/kg) in study area soil

Station	pH	EC (µS/cm)	OM%	CEC (ms/eq)	TC (%)	Total metal (mg/kg)		
						Pb	Cd	Zn
S1	8.21±0.19	256.37±67.87	5.42±2.35	38.98±4.82	5.38±4.02	19.01±8.25	1.57±0.82	38.53±15 .87
S2	8.21±0.26	240.7±41.94	4.87±2.76	37.05±7.36	6.47±5.16	15.43±3.44	2.46±1.46	45.41±14.46
S3	8.19±0.16	270.74±36.82	5.85±2.9	36.85±2.12	2.65±1.65	18.1±7.22	2.61±1.28	39.65±2.3

Table 2.The means concentration of metals in plants during the three years; 2014, 2015 and 2016.

Species	Station	Part of plant	Pb (mg/kg)	Cd (mg/kg)	Zn (mg/kg)
Ditrichia viscosa					
	S1	Roots	6.69±5.96	3.01±1.41	47.32±32.02
		Aboveground parts	9.25±8.73	2.51±1.53	53.55±8.98
	S2	Roots	10.88±10.68	2.82±1.57	29.83±15.08
		Aboveground parts	5.15±3.52	2.51±1.59	50.58±10.25
	S3	Roots	8.58±13.57	2.97±1.53	35.13±19.08
		Aboveground parts	4.54±3.07	2.32±1.97	45.28±9.45
Juncus effusus					
	S1	Roots	3.47±2.06	3.69±2.2	23.45±6.21
		Aboveground parts	7.37±4.15	2.02±0.5	36.04±10.08
	S2	Roots	10.25±9.56	1.94±1.17	63.15±36.49
		Aboveground parts	10.97±8.76	3.07±1.42	31.54±13.64
	S3	Roots	6.14±2.88	4.14±2.92	21.46±8.42
		Aboveground parts	6±4.36	2.93±1.43	46.38±20.16
Solanum nigrum					
	S1	Roots	12.03±10.63	2.04±1.48	34.08±17.41
		Aboveground parts	7.06±3.64	2.83±1.64	62.75±15.29
	S2	Roots	5.59±2.1	1.52±1.17	31.69±5.37
		Aboveground parts	8.26±4.33	2.41±1.51	56.21±19.56
	S3	Roots	7.11±6.12	2.55±1.38	35.16±21.88
		Aboveground parts	13.39±10.4	3.15±1.6	61.04±22.78

Table 2 shows metal content in plant tissue at the three sampling stations.

Ditrichia viscosa: Pb concentrations in roots were ranged from 6.69 mg/kg recorded in the first station to 10.88 mg/kg recorded in the second station and ranged from 4.54 mg/kg to 9.25 mg.kg^{-1}recorded in aboveground parts, Cd concentrations were ranged from 2.82 mg/kg to 3.01 mg.kg in roots and from 2.32 mg.kg to 2.51 mg.kg in aboveground parts while Zn values were ranged from 29.83 mg/kg to 47.32 mg/kg in roots and from 45.28 mg/kg to 53.55ppm in aboveground parts (Table 2).

Juncus effusus: Pb values were ranged from 3.47 mg/kg to 10.25 mg/kg in roots and from 6 mg/kg and 10.97 mg/kg in aboveground parts; Cd concentrations were ranged from 1.94 mg/kg to 4.14 mg/kg in roots and from 2.02 mg/kg to 3.07 mg/kg in aboveground parts; Zn values were ranged from 21.46 mg/kg to 63.15 mg/kg in roots and from 31.54 mg/kg to 46.38 mg/kg in aboveground parts (Table 2).

Solanum nigrum: Pb concentrations were ranged from 5.59 mg/kg to 12.03 mg/kg in roots and from 7.06 mg/kg to 13.39 mg/kg in aboveground parts; Cd concentrations were ranged from 1.52 mg/kg to 2.55 mg/kg in roots and from 2.41 mg/kg to 3.15 mg/kg in aboveground parts and Zn concentrations were ranged from 31.69 mg/kg to 35.16 mg/kg in roots and from 56.21 mg/kg to 62.75 mg/kg in aboveground parts (Table 2).

In a general way, metal concentrations varied according to the metal, the plant species and to the sampling station. Whereas lead concentrations in the root are higher than those in the aboveground parts in *Ditrichia viscosa* at the second and at the third station. On the contrary, in *Juncus effusus* and *Solanum nigrum* the highest concentrations of lead were recorded in the aboveground parts which underline the important dynamics of lead towards aerial parts. Analysis of the parts of plants lead concentrations showed that no significant differences between the parts of plants neither the three species in the three years of sampling (ANOVA, p>0.05). Cd concentrations varied between species; in *Solanum nigrum* the highest concentrations of Cd were recorded in the aboveground parts. Whereas in *Ditrichia viscosa* and *Juncus effusus*, higher concentrations were recorded in roots (table 2). Zn concentrations were ranged between 21.46 and 63.15 mg/kg, they were increasing from aboveground parts towards roots (aboveground parts >roots). Similar trends in Zn accumulation between the three species were recorded, no significant differences were found between the parts of plants neither the three species in the three years of sampling (p>0.05).

To evaluate the capability of plant species to extract and accumulate metal in the plant, the BCF was calculated and it represents the capacity of a plant species to remove a metal from soil or sediments and accumulate it in its tissues.

Table 3. Bio-Concentration Factor (BCF) for *Ditrichia viscosa*, *Juncus effusus* and *Solanum nigrum*

BCF		Pb	Cd	Zn
Detrichia viscosa	2014	1.03	1.46	2.05
	2015	2.16	0.82	1.09
	2016	1.67	1.21	3.12
Average of BCF		**1.62**	**1.16**	**2.09**
Juncus effusus	2014	3.34	0.88	1.32
	2015	3.57	0.90	1.64
	2016	1.04	1.13	1.74
Average of BCF		**2.65**	**0.97**	**1.57**
Solanum nigrum	2014	2.20	5.05	3.12
	2015	1.38	1.31	1.41
	2016	1.02	0.77	2.61
Average of BCF		**1.54**	**2.37**	**2.38**

Ditrichia viscosa: for Pb, BCFs are ranged from 1.03 in the year of 2014 to 2.16 in 2015 and medium of 1.62. For the Cd, the minimum of BCF was 0.82 in the year of 2015 and the maximum was 1.46 in the year of 2014 and the medium was 1.16. For the Zinc, the BCFs are ranged between 1.09 in 2015 and 3.12 in the year of 2016 and the medium was 2.09. So the BCFs of *Ditrichia viscosa* are in order of $BCF_{Zn} > BCF_{Pb} > BCF_{Cd}$.

Juncus effusus: for the lead, the BCFs were ranged from 1.04 in 2016 to 3.57 in 2015 and medium were 2.65. For the cadmium, these values were ranged between 0.88 in 2014 and 1.13 in the year of 2016, the medium was 0.97. For the zinc, the BCFs were ranged from 1.32 in 2014 and 1.74 in 2016 and the medium was 1.57.

Solanum nigrum: for Pb the BCFs were ranged from 1.02 in the year of 2016 to 2.20 in the year of 2014 and the medium was 1.54. For the Cd, these values were ranged from 0.77 in 2016 to 5.05 in 2014 and medium was 2.37. For the Zn, the BCFs were ranged between 1.41 in 2015 to 3.12 in 2014 and the medium factor was 2.38.

The values of translocation factor are presented in the Table 4.

According to the table 4, the TFs values ranged from 0.72 and 1.78 and averaged 1.25. The lowest TF value found in *Detrichia viscosa* for Pb (0.72), while the highest was found in *Solanum nigrum* for Zn.

The results shown in the table 4 indicate that *Detrichia viscosa* can translocate the zinc more than cadmium and lead, while *Juncus effusus* can translocate lead and zinc more than cadmium, but *Solanum nigrum* can translocate the three of the metals into their aboveground parts.

Table 4. Translocation factors (TFs) of the three species studied; *Ditrichia viscosa*, *Juncus effusus* and *Solanum nigrum* for the three metals analyzed; lead (Pb), Cadmium (Cd) and Zinc (Zn).

Species	TF (Pb)	TF(Cd)	TF(Zn)
Detrichia viscosa	0.72	0.83	1.33
Juncus effusus	1.22	0.82	1.05
Solanum nigrum	1.16	1.37	1.78

Table 5. Contamination factor (CF), Geo-accumulation index (Igeo) of technical landfill Demina center, soils, Algeria.

	Pb	Cd	Zn
Soil sample	19.72	2.56	43.19
Background values	20	0.3	95
CF	0.98	8.53	0.45
Igeo	-0.60	2.5	-1.722

all the values are in mg/kg
Background values according to Turekian et al 1961.

The results of the CF values of heavy metals are given in Table 5, on the average the CF values ranged from 0.45 of zinc to 8.53 for the cadmium. Waheshi et al, (2017), suggest the following terminology to describe uniformly the contamination factor**;** CF< 1 we have low contamination factor (indicating low sediment contamination of the substance in question), 1≤CF<3 moderate contamination factor, 3≤CF<6 significant contamination factors and if CF≥6 a very high contamination factor. According to this classification, the study area may be practically unpolluted with Zn and Pb (CF; 0.45 and 0.98 successively) and very contaminated with Cd (CF; 8.53).

Geoaccumulation factor was used to quantify the degree of anthropogenic contamination and compare different metals that appear in different ranges of concentration in the study areas (Hassaan et al., 2016).

The Igeo allows also the assessment of contamination by comparing current and pre-industrial concentrations (Loska et al. 2004). This method was originally used with bottom sediments by Muller (1969). Than it has been applied by many researchers Bakan & Balkas, (1999); Singh & Hasnain, (1999) and Zhang et al., (2007) to distinguish heavy metal levels in soils or sediments in anthropized areas from natural background levels in soils or equivalent sediments. However, this index depends on the appropriate natural background value. Since there are no geochemical background values for the study area, the average crust values used to calculate this index are those of Turekian et al (1961). It can also be applied to the evaluation of soil contamination (Benhaddya & Hadjel, 2014). The Igeo introduced by Gonzáles-Macías et al. (2006) was also used as a reference for estimating the extent of metal pollution.

The Igeo values are registered in table 5, they are ranged from -1.72 for the Zn to 2.5 for the Cd, according to Oumar et al, (2014) and Aydi, (2015) the Index of Geoaccumulation consists of 7 grades:

Table 6. the different classes of Igeo according to Oumar et al, (2014) and Aydi, (2015).

classe of Igeo	value of Igeo	index of Igeo
0	≤0	uncontaminated
1	0<Igeo≤1	uncontaminated to moderately contaminated
2	1<Igeo≤2	moderately contaminated
3	2<Igeo≤3	moderately to heavily contaminated
4	3<Igeo≤4	heavily contaminated
5	4<Igeo≤5	heavily to extramely contaminated
6	≥5	extramely contaminated

According to our results, the Igeo values indicate that the soil is uncontaminated with lead (Igeo=-0.60) and zinc (Igeo= -1.42), are less than zero, suggesting that the area is not polluted by these metals but it is moderately to heavily contaminated with cadmium (Igeo=2.5) along the study area. In conclusion, the heavy metals examined in the soils of the study area showed variations in concentrations due to the temporal variations in the distribution of metals.
The differences could be attributed to soil characteristics and land inputs due to variations in urban waste.

The landfills, considered to be posing a threat to human health through pollution of the air, soil and groundwater. Many studies show evidence of seriousness of hazards caused by landfills (Gworek *et al.* 2016; Koda *et al.* 2016). The bioavailibity of heavy metals is controlled by several factors and the quality of the soil is one of the most important of them.

Soil pH plays a major function in the sorption of heavy metals as it directly controls the solubility and hydrolysis of metal hydroxides, carbonates and phosphates. It also influences ion - pair formation, solubility of organic matter, as well as surface charge of certain (Tokalioglu et al.,2006).

Table 1 depicts the results of the physicochemical analysis of the landfill soil**.** The physical and chemical of soil are directly dependent on its pH value (Chatzistathis et al., 2015). Our results indicate that the values of pH of the soil are ranged between 8.19 and 8.21 which made landfill soil slightly alkaline, this is may be the result of partial ionization of acids present in the soil (Aydi et al., 2015). Also the nature of wastes which can be rich in various forms of calcium leads to a decrease in the acidity of the surface layer of the soil on which they were stored and an alkaline soil generally has low permeability to water and a high pH. According Jamali et al., (2005), the mobility and leaching of toxic metals increases, and their mobility and availability decreases as the pH approaches neutral or rises above 7.

There is well-documented evidence that the pH influences the transformation of organic matter in the soil (Tonon et al. 2010). Significantly higher pH values were found in landfill soils, which could be due to the decomposition of organic waste (Breza-Boruta et al., 2016). According to Wang et al., (2013), the kind of the matter accumulated and the processes of its decomposition can contribute to the change in the soil reaction.

Soil electrical conductivity (EC) measures the ability of soil water to carry electrical current. It's an effective way to map soil texture because smaller soil particles such as clay conduct more current than larger silt and sand particles. In our study, high levels recorded of EC values are due to the different ions in the soil solution. The EC of solutions is primarily affected by the ionic concentration, thus the proportion of landfill leachate. According (Corwin& Lesch, 2005) EC is an electrolytic process that takes place principally through water-filled pores, cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, and NH^{4+}) and anions ($SO4^{2-}$, Cl^{-}, NO^{3-}, and HCO^{3-}) from salts dissolved in soil water carry electrical charges and conduct the electrical current. Consequently, the concentration of ions determines the EC of soils. These ions are produced naturally by the biological degradation of organic matter present in wastes or soils. In agriculture EC has been used principally as a measure of soil salinity (table xx). EC is expressed in deci Siemens per meter (dS/m).

With respect to soil EC measurements, the latter were compared to the standard soil salinity and the results obtained confirm that the CET soil is Strongly Saline.

Table 7. Classes of salinity and EC (1 dS/m = 1 mmhos/cm; adapted from National Soil Survey Handbook, NRCS, 1993)

EC (dS/m)	Salinity class
< 2	Non-Saline
2 < 4	Very Slightly Saline
4 < 8	Slightly Saline
8 <16	Moderately Saline
≥ 16	Strongly Saline

The composition of organic waste (OW) and its effect on soil processes may change soil electrical conductivity (EC) (Carmo et al., 2016).

Cation exchange capacity (CEC**)** is a measure of how many cation can be retained on soil particle surfaces. This parameter particularly measures the ability of soils to allow for easy exchange of cations between its surface and solution (Wuana et al., 2010). CEC indicates the amount and type of clay in soils, as well as how much organic matter a soil contains. It is linked to the clay-humic complex. The value of the CEC of a soil is therefore a function of the quantities of clay and OM which it contains, but also of the nature of these elements and of the pH of the soil. The landfill soil had low OM content (about 5% on average) and high values of CEC (> of 36 meq/100g) indicate that the soil is clay-like. The relatively high levels of clay and CEC indicate the low permeability, hence low leach ability of heavy metals in the soil.

Usually, Organic matter (OM) composition it is a dynamic system so is varied and continues to change. This dynamic property results in different processes such as dissolution of minerals, the dissolution of lead in contaminated landfill soils is obviously facilitated by dissolved organic matter and the presence of organic matters will further affect some basic properties of the soil such as the CEC (LO et al., 1991). It is evident that organic matter and CEC played important roles on soil adsorption and OM was highly correlated with cation exchange capacity (Ramos et al., 2018). With respect to organic matters (OM) measurements, the latter were used to designate the landfill soil according to the standards reported by Normandy agronomic laboratory. According to these standards, the OM contents observed in the three station are soil moderately provided with MO (20‰<MO<30‰), is could be due to the age of the landfill which is newly built, so the OM is not yet totally degrading.

The presence of limestone gives the soil specific characteristics in terms of physical and chemical behavior and influences its biological activity. Its total absence results in progressive acidification, more or less rapid which is dependent on the soil pedoclimatic factors. The average limestone contents recorded for the landfill soils were less than 5%, which is indicative of their slightly calcareous character which can be explain their neutral character. This character has been confirmed by the adopted standards of the Normandy agronomic laboratory ($CaCO_3T \leq 5\%$, non-calcary) and (slightly calcareous; $5<CaCO3T\leq12.5\%$). Similar results were found by (Mouhoun-Chouaki et al., 2019).

As shown in Table 1, the highest concentrations in soil were these of Zn and the lowest were of Cd this heterogeneity is related to local soil parent rock, the age and the kinds of wastes deposed in the landfill center of Demina, these results agree with those of Yanqun et al., (2004) where he found that the highest concentration of heavy metals in the soil of his studied area was of Zn and the lowest was of the cadmium. The results reported by Zhang et al., 2010, showed that the concentrations of the Zn in the soil of Pearl river Estuary were the highest and those of Cd were the least. The BCF values showed that Cd is easy to accumulate by plants more than Zn (Zhang et al., 2010).

The efficacy of the plant species analyzed for phytoremediation was evaluated on the basis of the bioconcentration factor (BCF) and the translocation factor (TF).

The capacity of plants to removing and accumulating heavy metals from soil to their tissues differs according to the species (Chaplygin et al., 2018) and the efficiency of phytoextraction operation is controlled by several factors such as: soil properties (pH, organic matter, electric conductivity …), climate characteristics (precipitations) and its effects on the absorption and adsorption of metal in different phases of soil, the bioavailibity of the metal to plant which is controlled by the genetic and cytological properties of each plant species (Chandra Kisku et al ;2011) and the characteristics of the selected plants which must have a high aboveground biomass production, a fast growth, widely distribute, tolerate to the toxic effects of heavy metals (Michael et al., 2008; Saifullah et al ., 2009; Zuzanna et al ., 2015) and the number of metal hyperaccumulators which respond to these conditions is still growing (Sreve et al., 2003)., ,

In the present study, the age of individual plants, depth of roots and its immobilization or mobilization of metal in soil can influence on concentrations of the three metals and all metals levels. According to Kabata-pendias et al., (1992), heavy metals concentrations at these levels, supposed toxics to plants (5-30 mg/kg for Cd, 30-300 mg/kg for Pb and 100-400 mg/kg for Zn)

The BCF reflects the affinity of a given biomonitor to specific pollutants. High BCF values reflect higher affinity (Srivastava et al., 2019).

The bioconcentration factor is calculated to define the ability of plants to accumulate heavy metals in their tissues (Sekabira et al., 2011). According to Hassani et al., (2015) using BCF as classification factor; the *Achilleatenu ifolia Lam*, *Papaver piptostigma*, *Bromus tectorumL*, *Stipaho henacke riana*are hyperaccumulators of Cd, the *Centaurea persica, Papaver piptostigma, Bromus tectorum L, Pteropyrum aucheri* are hyperaccumulator of Zn and *Stipahohenackeriana and Peganum harmala L* are the hyperacumulator of the Pb.

According Sekabira et al., (2011) and IbneKamel et al., (2016) there are four categories of plants based in the BCF values; BCF<0.01 the plant is non-accumulator, ranged from 0.01 to 0.1, low accumulator, ranged from 0.1 to 1.0 plant is moderate accumulator and when the BCF is ranged from 1.0 to10 the plant is high accumulator or hyperaccumulator, and according to Forjan et al., 2018: the plants have phytoextraction capacity when the value of BCF is greater than 1, and according to Rana et al., 2018, the plant species were recommended for phytoextraction operation if they have BCFs and TFs more than one, and they were recommended for phytostabilisation if they have BCFs bigger than one and TFs lower than one.

The present study indicates that:

Ditrichia viscosa: was recommended for phytoextraction operation of Zinc (BCF=2.09) and TF=1.33>1) and recommended for phytostabilisation operation of both lead (BCF=1.62; TF=0.72) and cadmium (BCF=1.161 and TF=0.83).

Juncus effusus: was recommended for phytoextraction operation of both lead (BCF=2.65; TF=1.22>1) and zinc (BCF=1.57; TF=1.05>1). Ullah et al., (2011), found that *Juncus effusus L* can survive under Cd stress without any symptoms of phytotoxicity.

Solanum nigrum: is recommended for phytoextraction of the three metals; lead (BCF=1.54; TF=1.16), Cadmium (BCF=2.37; TF=1.37) and Zinc (BCF=2.38; TF=1.78).

Landfill center soil has a low contamination factor with lead (CF=0.98) and zinc (CF=0.45) but it has a very high contamination factor with cadmium (CF=8.53), those results are confirmed with the results of Igeo which showed that the soil is uncontaminated with the lead (Igeo=-0.60) and zinc (Igeo=-1.42) and these elements are practically unchanged by anthropogenic influences while it is moderately to heavily contaminated with cadmium (Igeo=2.5). This dangerous metal may be derived from urban waste. Our results agree with those obtained by Aydi, (2015) who considered that his studied soil was uncontaminated with Zn and Pb but uncontaminated to contaminated with Cd based on the values of Igeo,

All those variations in factors values may be the result of the nature and variation of wastes dispose on the landfill, to the climate characteristics (precipitation), to the properties of the metals (absorption and bio-availibity), to the background concentrations of each metal and to the physico-chemical properties of soil and its effects on the metals behavior in the soil.

CONCLUSION

Among the several factors that influence the phytoextraction efficiency of a toxic element from polluted soils (e.g., soils of landfill centers, mining and industrial sites, metalliferous soils), the selection of plants that have ability to remove effectively metals from soil and accumulate in their tissues. The best criteria for selection of plant species for phytoremediation are the BCF and TF. The results presented in this paper indicated the great potential of the three species to extract efficiently the three heavy metals from soils (BCFs>1). This study indicates also that *Solanum nigrum* can translocate the three studied metals from their roots into their aboveground parts (TF> 1). For these reasons we can conclude that: the *Solanum nigrum* is recommended for the phytoextraction operation, *Ditrichia viscosa* is recommended for the phytoextraction of zinc (BCF>1 and for phytostabilisation of the both of cadmium and lead and *Juncus effusus* is recommended for phytoextraction operation of lead and zinc because of its ability to accumulate and transfer them from soil to aboveground parts.

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CONFLICT OF INTEREST

The authors of this research declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, has been observed by the authors and the article has not been published in anywhere in the world.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research

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