Heavy metals accumulation in *Hertia cheirifolia* along the highway in Setif region, Algeria

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Abstract. Belguidoum A, Lograda T, Ramdani M. 2020. Heavy metals accumulation in *Hertia cheirifolia* along the highway in Setif region, Algeria. *Biodiversitas* 21: 2786-2793. The aim of this work was to study the possibility of using *Hertia cheirifolia* spontaneous plant, generally present in uncultivated environments, as an indicator of pollution. The aerial parts of ten *H. cheirifolia* populations were collected along the East-West highway. Sampling is carried out in areas considered polluted or low contaminated in the region of Setif. Nine metallic trace elements concentrations (Pb, Zn, Cu, Fe, Mn, Cd, Ag, Bi, and Sb) were determined, for each population, by Atomic Absorption Spectrophotometry with Flame (AASF). Statistical analyzes were performed using mainly box and whisker diagrams, principal component analysis, and UPGMA. The concentrations detected for contaminants (MTE), in general, were very high, far exceeding international certified standards. The MTE concentrations in different populations were calculated for each metal and a positive correlation is observed. The order of MTE in the plant was found as follows: Fe > Zn > Mn > Pb > Sb > Cu > Bi > Ag > Cd. The Fe concentrations are very high in *H. cheirifolia* with an average of 3600 ± 1491.5 mg/kg. The populations of *H. cheirifolia* have shown a significant capacity to accumulate heavy metals. The presence of metal ions in the aerial parts of the plant designates that *H. cheirifolia* is a super accumulator of MTE and can be used as a bioindicator, which opens up prospects for its application to soils phytoremediation.

Keywords: Algeria, bioaccumulation, bioindication, heavy metal, *Hertia cheirifolia*, Setif

INTRODUCTION

The term metallic trace elements (MTE), is assimilated to the term “heavy metals”, designates metals and metalloids often reputed to be toxic, present in low dose environments (Connelly 2005; Rollin and Quiot 2006; Hasanuzzaman et al. 2018). The accumulation of heavy metals, natural components of the environment, is worrying. This occurrence is attributed to rapid population growth, urbanization, and the expansion of industrial activities (Aksoy et al. 2000; Simmons et al. 2003; Aslam et al. 2012; Tossapol et al. 2015).

The presence of MTE in the soil is not indicative of pollution (Baize 2000), because the rates of MTE in the soil depend on the rock of origin (Dung et al. 2013). Road transport contaminates the atmosphere, water, and soil near highways by atmospheric fallout. Traffic pollutants include potentially toxic metals (Caussy et al. 2003; Akbar et al. 2006; Olukanniand Adebiyi 2012). Many studies have shown contamination by these elements, near highways (Turer and Maynard 2003; Atayese et al. 2010). Plants are the basis of the food chain and can absorb MTE ground by biosorption or bioaccumulation (Atayese et al. 2010). The levels of heavy metals in roadside plants vary by species, so-called hyper-accumulating plants. These plants are able to accumulate high levels of MTE at concentrations 10 to 100 times the value tolerated by most plants (Krämer and Chardonnens 2001; Gratao et al. 2005; Gav et al. 2015).

Plants are used in bioindication; it is a low-cost process to assess the degree of pollution (Rucandio et al. 2011). *Hertia cheirifolia* species is considered a heavy metal accumulator and has a potential for phytoremediation of metallic trace elements (Lograda et al. 2016). The aims of the work are the study the bioaccumulation potential of MTE by *Hertia cheirifolia*, collected on the along a highway, and to identify its potential for phytoremediation.

MATERIALS AND METHODS

Study area

Ten stations, located at Setif region, Algeria (Table 1), were selected for the sampling of the species *Hertia cheirifolia* (Figure 1). The climax of the study area is semi-arid, cold in winter and hot in summer. The average annual rainfall is 322mm and rarely exceeds 500mm and the annual average temperature is 15°C.

Selection of the plant

*Hertia cheirifolia*, synonymous with *Othonnopsis cheirifolia*, is a species with very original leaves, persistent, gray, thick, forming a dense ground cover. In spring, the flowering is bright yellow. This species is native to Algeria and Tunisia. The selection of *H. cheirifolia* is based on a previous study on the bioaccumulation of heavy metals in this species (Lograda et al. 2016). It is a very popular plant in the region. The samples were transported to the laboratory in paper bags.
Atom to T
obtain a fine powder measured, crushed, and sieved through a nylon sieve to

It consists of eliminating any atmospheric deposit. After measuring the fresh weight, samples of 400g of plants were dried at 80 °C for 48 h, and then the dry weight was measured, crushed, and sieved through a nylon sieve to obtain a fine powder.

Mineralization
The method of Tauzin and Just (Adjiri et al. 2018) was used. It consists in calcining 1 to 2g (stems, leaves, and roots crushed) in a muffle furnace at 450°C for four hours. The ash thus obtained are mineralized by aqua regia (25% HNO3 and 75% HCl), then reduced to dry until discoloration of the mineral deposit occurs, on a sand bath. The residue is dissolved in 10ml HCl 5%. Then filtered on Whatman, paper with 0.45µm of diameter, and completed to 20 ml with HCl 5%. Heavy metals were assayed by Atomic Absorption Spectrophotometer with Flame (AASF) in the laboratory of Valorization of Natural Biological Resources, Setif University.

Analytical procedures for MTE concentrations
The concentrations of the following elements (Pb, Zn, Cu, Fe, Mn, Cd, Ag, Bi, and Sb), were determined by Atomic Absorption Spectrophotometry, with Flame (AASF). There are no established standards of trace elements concentration in ppm. To interpret the results of each element studied, we use as standard reference values, the unit's concentration ranges. The obtained results in (g/l) are transformed into mg/kg using the following relationship:

\[
T \left( \frac{mg}{kg} \right) = C \frac{V}{S}
\]

Where; T: element concentration in mg/kg; C: concentration of the element in mg/l determined by the calibration curve; V: extraction volume in ml and S: sample weight in grams.

Statistical analysis
Data were first subjected to Principal Components Analysis (PCA) to examine the relationships among the trace elements and the bioaccumulation by this plant and the relationships between the presence of these elements and the vehicle circulations. Cluster analysis, Un-weighted pair group method with arithmetic mean (UPGMA), was carried out on the original variables and on the Manhattan distance matrix to seek for hierarchical associations among the elements and stations. The statistical analyses were carried out using STATISTICA 10 software.
RESULTS AND DISCUSSION

Results

After selecting the sites of studies; the aerial parts of *Hertia cheirifolia* were collected and subjected to analysis of heavy metals by AASF. This analysis revealed the presence of high rates of MTE in this species (Table 2).

All elements quantified in *Hertia cheirifolia* populations far exceed the standard values. The concentrations determined for contaminants (MTE), in general, were very high, far exceeding international certified standards values (Figure 2). The concentration of MTE in the different populations was calculated for each metal and a positive correlation is observed. The order of MTE in the plant was found as follows: Fe > Zn > Mn > Pb > Sb > Cu > Bi > Ag > Cd.

The cluster analysis clearly shows the presence of two clades (Figure 3). The element Fe, present in populations with very high concentrations with an average of (3600 ± 1491.5 mg/kg), forms the first clade. In the second clade, Zn forms a subgroup and isolates itself from the rest of the elements with an average concentration of (1000 ± 434.6 mg/kg), followed by Mn and Pb. The UPGMA confirms the correlation that exists between the concentrations of MTE in the different populations.

The concentrations of Zn, Pb, Fe, and Mn, in *H. cheirifolia*, are highly variable (Figure 4). Iron is very high in all stations with rates exceeding the standard value. The samples of Kharzet Youcef (pushing on the floor of the mine) and the Public discharge CET reveal a presence of high levels of Zn and Mn elements, far exceeding international standards.

Cd and Ag although their concentrations exceed the standard values, their concentrations in *H. cheirifolia* are low compared to the other elements like Sb, Cu, and Bi (Figure 5).

*Hertia cheirifolia* populations show very high differences in the concentrations of the MTE. To compare profiles with Elements trace metallic we considered each MTE as a quantitative variable. The spatial three-dimensional projection of the 10 populations based on the three main axes from the PCA (Figure 6), shows that the populations of Kharzet Youcef, Unit ENPEC and Public discharge CET are distinctly separated, but the others populations studied are not clearly distinguished and their separation into homogeneous groups is less clear.

The UPGMA clusters analysis based on the linkage distance confirms the results of the PCA and separates *H. cheirifolia* populations in two distinct clades (Figure 7). These populations’ clustering in small groups indicates differences in the MTE concentrations. The first cluster regroups Ain Oulmen and Kharzet Youcef populations, who are characterized by a high content of Fe, Zn, and Mn, these two stations are located near a Zinc mine.

The second cluster is composed of three subgroups: The unit of ENPEC and the Public discharge CET are characterized by a high level of Fe, Pb, Zn, Mn, Sb, and Bi. The second subgroup includes the populations of Ouled Sabor, Sidi Haidere, Industrial Zone, Elhamelette, Smara, and Mezloud; those populations are characterized by a high level of Fe, Zn, Sb, and Bi.

Discussion

The populations of *Hertia cheirifolia* analyzed showed variable MTE accumulation responses in the different stations. For most elements, studied concentrations are high, in particular for Fe, Zn, Mn, Pb, and Sb. These elements are, generally considered to be mainly of anthropogenic origin (Adimalla and Wang 2018; Djeddi et al. 2018; Adimalla et al. 2019; Saljnikov et al. 2019; Sun et al. 2019). The high sample contamination has many origins, including, the mining activity of Kharzet Youcef, Industrial Zone, Unit ENPEC (manufacture of Batteries), Technical landfill center, Sidi Haidere (Scrap depot) and the vehicle traffic, which can transmit this contamination to the food chain (Ben Ghaya et al. 2013).

Table 2. Accumulation of metallic trace elements by *Hertia cheirifolia*

| Stations            | Pb  | Zn  | Cu  | Fe  | Mn  | Cd  | Ag  | Bi  | Sb  |
|---------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Ouled Sabor         | 68  | 800 | 70  | 3800| 230 | 7   | 8   | 71  | 170 |
| El Hamelette        | 21  | 800 | 89  | 2700| 200 | 6   | 6   | 60  | 120 |
| Smara               | 90  | 700 | 100 | 2400| 530 | 7   | 7   | 62  | 160 |
| Sidi Haidere        | 45  | 900 | 150 | 3100| 310 | 11  | 9   | 62  | 170 |
| Public discharge CET| 175 | 1800| 124 | 3300| 260 | 11  | 9   | 64  | 190 |
| Industrial zone     | 71  | 800 | 92  | 3300| 460 | 9   | 11  | 66  | 70  |
| Unit ENPEC          | 1100| 1000| 111 | 2300| 420 | 8   | 10  | 65  | 170 |
| Mezoulo             | 27  | 600 | 96  | 2700| 580 | 6   | 10  | 50  | 150 |
| Ain Oulmen          | 26  | 800 | 73  | 5400| 380 | 5   | 8   | 52  | 100 |
| Kharzet Youcef      | 44  | 1800| 62  | 7000| 300 | 15  | 10  | 37  | 90  |
| Average             | 166.7| 1000| 96.7| 3600| 367 | 8.5 | 8.8 | 58.9| 139 |
| Min.                | 21  | 600 | 62  | 2300| 200 | 5   | 6   | 37  | 70  |
| Max.                | 1100| 1800| 150 | 7000| 580 | 15  | 11  | 71  | 190 |
| SD                  | 331 | 434.6| 26.6| 1491.5| 128.9| 3.1 | 1.6 | 9.9 | 41  |
| RSD                 | 198.56| 43.46| 27.5| 41.43| 35.12| 36.47| 18.18| 16.8| 29.49|
| Standard value      | 1   | 50  | 10  | 150 | 200 | 0.05| 0.2 | 0.06| 0.1 |
The concentrations of Pb, Cu, Zn, Mn, Cd, and Fe are very high in most samples of *H. cheirifolia* and exceed the standards values, according to Cheng (2003) species with this characteristic can be used in bioindication to monitor soil and area contamination. *H. cheirifolia* can be used in the phytoextraction of MTE, based on the use of potential hyper-accumulation to extract the MTE from the soil and transfer them to the aerial parts (Kambhampati et al. 2003; Gardea-Torresdey et al. 2005; Mnasri et al. 2015).

The average Iron concentration exceeds the standard value in the *H. cheirifolia* plant; this high rate is due to the genetic and physiological capacity of the plant to accumulate this element. Fe is an element of the soil that undergoes significant bioaccumulation in plants that produce chelators (Marrassini et al. 2018). The high values for Zn and Pb in *H. cheirifolia* exceed certified standards. These concentrations are closely linked to emissions from heavy traffic (Francová et al. 2017; Bentum et al. 2018; Hassan 2018; Adimalla et al. 2019; Kumar et al. 2019).
The Unit ENPEC Station, which is well known by this electrochemical product and waste of heavy metals, recorded very high value of Pb, this element, can pollute the surrounding soil through releases and atmospheric deposits (Zhang et al. 2015; Dron et al. 2016). Similar studies were carried out in the mining regions, and the same conclusions were issued (Wu et al. 2020). The concentrations of Zn, Fe, and Cd exceed regulatory levels in the region of Kharzet Youcef, which is associated with mining. Similar contamination has been reported in similar areas (Lograda et al. 2016; Drahota et al. 2018; Hesami et al. 2018).

**Figure 4.** Concentration of Fe, Zn, Mn, and Pb in *Hertia cheirifolia*

**Figure 5.** Concentration of Sb, Cu, Bi, Cd, and Ag in *Hertia cheirifolia*
The bismuth concentrations are very high, if we compare them with the Pb distribution rate, we notice similar values between the stations most contaminated by the two elements (Unit ENPEC, Public discharge CET and Industrial zone). Bi is often a sub-product of lead mining, so most industrial releases containing Pb imply the presence of traces of bismuth (Tighe et al. 2019). However, the highest concentration of Bi is recorded in the Ouled Saber station, this concentration is probably due to the agricultural activity that characterizes the region; the application of fertilizers produces relatively high concentrations of Bismuth (Kabata-Pendias et al. 2007). The concentration of Sb is high in most of the stations studied; this is mainly due to road traffic, ash from the waste, which burns especially in summer (Bisson et al. 2007), industrial activity, and road traffic (Negral et al. 2020).

The high concentrations of MTE found in the uncontrolled open landfill site have several origins. The high levels of Zn, Sb, and Pb are the consequence of the...
presence of leachate, which contains many mineral contaminants (Baziene et al. 2020). Authors made the same observations confirming that the leachate is highly polluted by MTE, with major contamination by Zn and Pb (Koné et al. 2007; Mehdi et al. 2007; Sangaré et al. 2016). A very significant accumulation of MTE was noted in the station of Sidi Haider (station that shelters an automobile breakage), this accumulation is the consequence of contamination by the products of decomposition of this waste materials. Several studies have reported this type of contamination of soil and vegetation by the deposition of particles from automobile wear (Lange et al. 2017; Zanello et al. 2018; Bernardino et al. 2019; Mihankhah et al. 2020).

The high Cu level in the Sidi Haider station of up to 150 mg/kg is due to the presence of this auto box; Several studies have proven the relationship between Cu levels and certain polluting sources (paint, brake pads, tires, and car wiring) (Winther and Slentó 2010; Hsu et al. 2018; Barbosa et al. 2020).

Another fact that arises is that the plants having more accumulation properties can be used for removing the heavy metal toxicity in the roadside environment. Therefore, H. cheirifolia offers prospects of application of phytoremediation, and can be identified as tolerant to the presence of high concentrations of ETM, may be subject to further studies, particularly to effect elections of bio-accumulating populations.

In conclusion, this study gives evidence for the accumulation of Pb, Zn, Cu, Fe, Mn, Cd, Ag, Bi, and Sb in H. cheirifolia aerial parts sampled in the Setif area. It has shown that the sampled stations are heavily polluted by the presence of high levels of MTE. Overall, the results report that H. cheirifolia is good bioindicator and can be used in sol pollution-monitoring studies. The most frequent throughout the site, which offers prospects of application of phytoremediation. The results showed that both plants were able to uptake a considerable amount of MTE, indicating that H. cheirifolia has potential for elements phytoremediation.

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REFERENCES

Adimalla N, Qian H, Wang H. 2019. Assessment of heavy metal (HM) contamination in agricultural soil lands in northern Telangana, India: an approach of spatial distribution and multivariate statistical analysis. Environ Monit Assess 191 (4): 246. DOI: 10.1007/s11661-019-7408-1

Adimalla N, Wang H. 2018. Distribution, contamination, and health risk assessment of heavy metals in surface soils from northern Telangana, India. Arabian J Geosci 11 (21): 684 (1-15). DOI: 10.1007/s12517-018-4028-y

Adjiri F, Ramdani M, Lograda T, Chalard P. 2018. Bio Monitoring of Metal Trace Elements by Epiphytic Lichen in the Bordj Bou Arreridj Area, East of Algeria Sch Acad J Biosci. 6 (2): 199-208. DOI: 10.11276/sajb.2018.6.2.112

Akbar KF, Hale WH, Headley AD. Athar M. 2006. Heavy metal contamination of roadside soils of Northern England. Soil Water Res 1 (4): 158-163.

Aksoy A, Sahin U, Duman F. 2000. Robinia pseudoacacia L. as a possible biomonitor of heavy metal pollution in Kayseri. Türk J Bot 24 (5): 279-284.

Atayese MO, Ephigbadon AI, Uluwa KA, Adesodun JK. 2010. Heavy metal contamination of amaranthus grown along major highways in Lagos, Nigeria. Afr Crop Sci J 16 (4): 225-235. DOI: 10.4314/acq.v16i4.54390

Baize D. 2000. Teneurs totales en métaux lourds dans les sols français premiers résultats du programme ASPITET. Courrier de l’Environnement de l'INRA 39: 39-54.

Barbosa JZ, Pogger GC, Teixeira WWW, Motta ACV, Prior SA, Curi N. 2020. Assessing soil contamination in automobile scrap yards by portable X-ray fluorescence spectrometry and magnetic susceptibility. Environ Monit Assess 192 (1): 46. DOI: 10.1007/s10661-019-8025-8

Baziene K, Tetsman I, Albrektiene R. 2020. Level of Pollution on Surrounding Environment from Landfill Aftercare. Intl J Environ Res Public Health 17 (6): 2007 (1-14). DOI: 10.3390/ijerph17062007.

Ben Ghaya A, Hamrouni L, Mastouri Y, Hanana M, Charles G. 2013. Impacts of toxic metals on vegetation of the Djebel Hallouf mine in the area of Sidi Bouaouane in BouSalem Northwestern Tunisia. Geo Eco Trop. 37 (2): 243-254.

Bentum JK, Essumang DK, Tuffuro JK, Agyakum I. 2010. Analysis of heavy metals in roadside soils and crops along the Obansando way in the Accra metropolis. Intl J Biol Chem Sci. 4 (3): 803-808. DOI: 10.4314/jbcs.v4i3.60517

Bernardino CA, Mahler CF, Santelli RE, Freire AS, Bazz BF, Novo LA. 2019. Metal accumulation in roadside soils of Rio de Janeiro, Brazil: impact of traffic volume, road age, and urbanization level. Environ Monit Assess 191: 156 (1-14). DOI: 10.1007/s10661-019-7265-y

Bisson M, Bonnomet V, Migne-Fournille V, Jolibois G, Gay G, Lefèvre JP, Tack K. 2007. INERIS - Fiche de données toxicologiques et environnementales des substances chimiques. Antimoine et ses dérivés... Ver. 2. 54p. https://substances.neries.fr/fr/substance/pd/7211

Caussy D, Gochfeld M, Gurzau E, Neagu C, Ruedel H. 2003. Lessons from case studies of metals: investigating exposure, bioavailability and risk. Ecotoxicology and environmental safety 56 (1): 45-51. DOI: 10.1016/S0147-6513(03)00049-6

Cheng S. 2003. Effects of heavy metals on plants and resistance mechanisms. Environ Sci Pollut Res 10 (4): 256-264. DOI: 10.1023/B:ESPR.2002.11.141.2

Connelly NG, Danthu T, Hartshorn RM, Hutton AT. 2005. Nomenclature of inorganic chemistry. Published for the International Union of Pure and Applied Chemistry (IUPAC). R Soc Chem. 373: 377.

Djedj Hamssa, Salihia Khennif, Nacreddine Douina, Keddari Fatima-Zohra, Afrim-Mehennou. 2018. Teneurs Des Éléments Traces Métalliques Cu, Zn Et Pb Des Sédiments Du Barrage Bén Haroun (Nord-Est De l’Algérie). Eur Sci J 14 (15): 269-286. DOI: 10.19044/esj.2018.v14n15p269

Drahota P, Raus K, Ryčillová E, Rohovec J. 2018. Bio accessibility of As, Cu, Pb, and Zn in mine waste, urban soil, and road dust in the historical mining village of Karš, Czech Republic. Environ Geochem Health 40 (4): 1495-1512. DOI: 10.1007/s10653-017-9999-1

Dung TTT, Cappuyens V, Swennen R, Phung NK. 2013. From geochemical background determination to pollution assessment of heavy metals in sediments and soils. Rev Environ Sci Biotechnol 12 (4): 335-353. DOI: 10.1007/s11806-013-9315-1

Francová A, Chrastný V, Silírová H, Vítková M, Kocourková J, Komárek M. 2017. Evaluating the suitability of different environmental samples for tracing atmospheric pollution in industrial areas. Environ Pollut 220: 286-297. DOI: 10.1016/j.envpol.2016.09.062
Phytoaccumulation of heavy metals and study of the metal coordination by X-ray absorption spectroscopy. Coord. Chem. Rev. 249: 1797-1810. DOI: 10.1016/j.ccr.2005.01.001

Gav BL, Aremu MO, Usman Y, Tsavjin JVN. 2015. Bioaccumulation of trace metals in fishes from selected rivers of Nasarawa state, Nigeria. Int J Chem Res 5 (3): 1-10.

Gratão PL, Prasad MNV, Cardoso PF, Lea PJ, Azevedo RA. 2005. Phytoaccumulation: green technology for the cleanup of toxic metals in the environment. Braz J Plant Physiol 17 (1): 53-64. DOI: 10.1590/S1677-04202005000100005

Hasanuzzaman M, Nahar K, Fujita M (eds.). 2018. Plants under Metal and Metallloid Stress. Responses, Tolerance and Remediation, Springer, Singapore. DOI: 10.1007/978-981-13-2242-6

Hassan EL, Hadli. 2018. Pollution des sols à Proximité des Routes: Impact des Eléments Traces Métalliques (ETM) sur les sols à Proximité de la Voie de Contournement des Villes de Rabat et Salé (Maroc). Eur J Sci Res 150: 60-72.

Hesami R, Salimi A, Ghaderian SM. 2018. Lead, zinc, and cadmium uptake, accumulation and phytoaccumulation by plants growing around Tange Douzan lead-zinc mine, Iran. Environ Sci Pollut Res 25 (9): 8701-8714. DOI: 10.1007/s11356-017-1156-y

Hsu DJ, Chung SH, Dong JF, Shih HC, Chang HB, Chien YC. 2018. Lead, zinc, and cadmium in soils and vegetables near a re-refinish painters to toxic metals. Int J Environ Res Public Health 15 (5): 899. DOI: 10.3390/ijerph15050899

Julien Dron, Annabelle Austruy, Yannick Agnan, Aude Ratiere, Philippe Chamaret. 2016. Biomonitoring with lichens in the industrial-portuary zone of Fos-sur-Mer (France): Feedback on three years of monitoring at a local collective scale. Pollution atmosphérique 228 (1): 1-17. DOI: 10.4267/pollution-atmospherique.5392

Kabata-Pendias A, Mukherjee AB. 2007. Trace Elements from Soil to Human. Springer Science and Business Media, Berlin.

Kambampati MS, Begonia GB, Begonia MFT, Bufford Y. 2003. Bioaccumulation of trace metals in fishes from selected rivers of Nasarawa state, Nigeria. Int J Chem Res 5 (3): 1-10.

Kendall B, Dron. 2014. Annabelle Austruy, Yannick Agnan, Aude Ratiere, Philippe Chamaret. 2016. Biomonitoring with lichens in the industrial-portuary zone of Fos-sur-Mer (France): Feedback on three years of monitoring at a local collective scale. Pollution atmosphérique 228 (1): 1-17.

Köndgen M, Drame D, Karim Sory T, Ardjouma D, Houenou PV. 2007. Elemental patterns from different marchés of the zone minière de Lubumbashi. J Appl Biosci 66: 5106-5113. [France].

Koné M, Dramane D, Karim Sory T, Ardjouma D, Houenou PV. 2007. Eléments traces métalliques dans les sols et les eaux souterraines. Rapp. D’étude INERIS. [France].

Rucandio MI, Petit-Dominguez MD, Fidalgo-Hijano C, García-Giménez R. 2011. Biomonitoring of chemical elements in an urban environment using arboreal and bush plant species. Environ Sci Pollut Res 18 (1): 51-63. DOI: 10.1007/s11356-010-0530-y

Salminen K, Eronen T, Meriv M, Čakmak D, Jaramaz D, Perovici V, Antid-Mladenovic S, Pavlovic P. 2019. Pollution indices and sources assessment of heavy metal contamination of agricultural soils near the thermal power plant. Environ Geochem Health 41: 2265-2279. DOI: 10.1007/s10653-019-0281-y

Sangaré, N, Yao KM, Kwa-Kofi EK, Kouassi NL, Soro BM, Kouassi AM. 2016. Évaluation de la qualité des ressources en eau près de la décharge urbaine non-décomposée d’Akorouedé par le calcul des risques cancérigènes et des indices de pollution. Afrique Science 12 (5): 279-290.

Simmons RW, Pongsukul P, Chuany RL, Sayisaiapnich D, Klinhoklap S, Nobanton W. 2003. The relative exclusion of zinc and iron from rice grain in relation to rice grain cadmium as compared to soybean: Implications for human health. Plant Soil 257: 163-170. DOI: 10.1023/A:1026242811667.

Sun L, Guo D, Liu K, Meng H, Zheng Y, Yuan F, Zhu G. 2019. Levels, sources, and spatial distribution of heavy metals in soils from a typical coal industrial city of Tangshan, China. Catena 175: 101-109.

Tighe M, Beidinger H, Knaub C, Sisk M, Peaslee GF, Lieberman M. 2011. Feedback on three years of monitoring at a local collective scale. Pollution atmosphérique 228 (1): 1-17.

Torresdey JL, Peralta I, Anesini C. 2007. Implications of organic acids in these processes. Front Plant Sci 6: 507-5106.

Turger DG, Maynard BJ. 2011. Biomonitoring of chemical elements in an urban environment using arboreal and bush plant species. Environ Sci Pollut Res 18 (1): 51-63. DOI: 10.1007/s11356-010-0530-y

Wu Z, Chen Y, Han Y, Ke T, Liu Y. 2020. Pollution indices and sources assessment of heavy metal contamination of agricultural soils near the thermal power plant. Environ Geochem Health 41: 2265-2279. DOI: 10.1007/s10653-019-0281-y

Zhang C, Yang Y, Li W, Zhang C, Zhang R, Mei Y, Liao X, Liu Y. 2015. Spatial distribution and ecological risk assessment of trace metals in urban soils in Wuhan, central China. Environ Monit Assess. 187: 556-572. DOI: 10.1007/s10661-015-4762-0

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