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Impact of Mining Activity on Soils and Plants in the Vicinity of a Zn-Pb Mine (Draa Lasfar, Marrakech - Morocco)

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ABSTRACT

The pollution generated by metallic trace elements discharged by mines into the environment can become a very worrying source of contamination for soil, water and plants. The characterization of the chemical properties of metals in mine tailings and soils is of crucial importance to assess the risk of their potential mobility and therefore their bioavailability. In this paper, the bioavailability of metallic trace elements in agricultural soils in the vicinity of the Draa Lasfar mine in the northwest of Marrakech city (Morocco) was studied by determining the contents of Cd, Cu, Pb and Zn in soils and in two plants: wheat (main food for the human population) and couch grass (main food for livestock). The results showed that these metals move from agricultural land to plants. They also showed that couch grass seems to strongly absorb and accumulate metallic trace elements present in the soil; it removes considerable amounts of metallic trace elements from the soil with its deeply penetrating root system.

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INTRODUCTION

Due to rapid economic progress, industrial development and demographic expansion, heavy metal contamination has become increasingly worrying and prominent and one of the major environmental problems globally (Rajeshkumar and Li, 2018; Zhu et al., 2020), requiring more interest to preserve the integrity of the environment and the public health. Furthermore, : metallic trace elements (MTE) released in mining wastes from intense industrial or mining activity can be found in high concentrations in terrestrial environments, constituting consequently a real threat to water, soil and plants (Rajeshkumar and Li, 2018, Okogwu et al., 2019).

Today, risk assessment constitutes a major decision-making tool for the management of different environmental situations. One of the aspects of food safety (for humans and livestock)

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is the control of metallic trace elements levels in foods of plant origin. Present in water and the terrestrial environment, certain metallic trace elements such as Zn, Se, etc., are necessary for the normal functioning of plants. They play an important role in the transformation and growth of matter (Rehman et al., 2021), mainly in the enzymatic mechanisms of plants (Stadman, 2002). A low concentration of these elements in the environment generally has a positive effect and stimulates the activity of living organisms (Rehman et al., 2021, Shah et al., 2010). Regardless of the origin of the metals in the soil, excessive levels can result in the degradation of the quality of soils and consequently of agricultural products as well as the reduction of crop yields (Rahimi et al., 2017; Wang-da *et al.* 2006; Yang et al., 2005). They can pose risks to human and animal health and to the ecosystems (Wu and Zhang 2010; Yang *et al.*, 2009). The threat of metals to human and animal health is worsening and multiplying due to their persistence in the environment. This concern has become more worrying with the latest studies which have highlighted the possibility of the transfer of these elements in the various links of the food chain by accumulation from contaminated water (Main Uddin et al., 2021, Chen et al., 2020, Wu and Zhang 2010).

The present study was conducted to assess four metallic trace elements (Cd, Cu, Pb and Zn) levels in the soil collected from Draa Lasfar mining zone in Marrakech city, as well as only two plants (wheat and couch grass) grown on the soil in order to provide information about the status of heavy metal pollution in vegetable fields and to evaluate the potential health effect generated by the consumption of these two plants.

Site description

Draa Lasfar mine, involves a pyrite deposit located 10 km northwest of Marrakech city (Figure 1) that can pose a risk for the environment due to discharge of tailings all around the mine area (Avila et al., 2012). The Draa Lasfar deposit contains 10 Mt of ore grading 5.3 wt.% Zn, 2wt.% Pb, 0.3 wt.% Cu (Barkouch and Pineau, 2016) and their ore bodies consist dominantly of pyrrhotite (70 to 95 vol.% of sulphides, but commonly up to 90 to 95 vol.% in Zn and Cu-depleted zones), with lesser sphalerite (1 to 10 vol.%), galena (0.5 to5 vol.%) and chalcopyrite (1 to 5 vol.%), and with local concentrations of deformed pyrite (2 to 3 vol.% of total sulphides) being arsenopyrite the most common of the minor minerals (Marcoux et al., 2008).

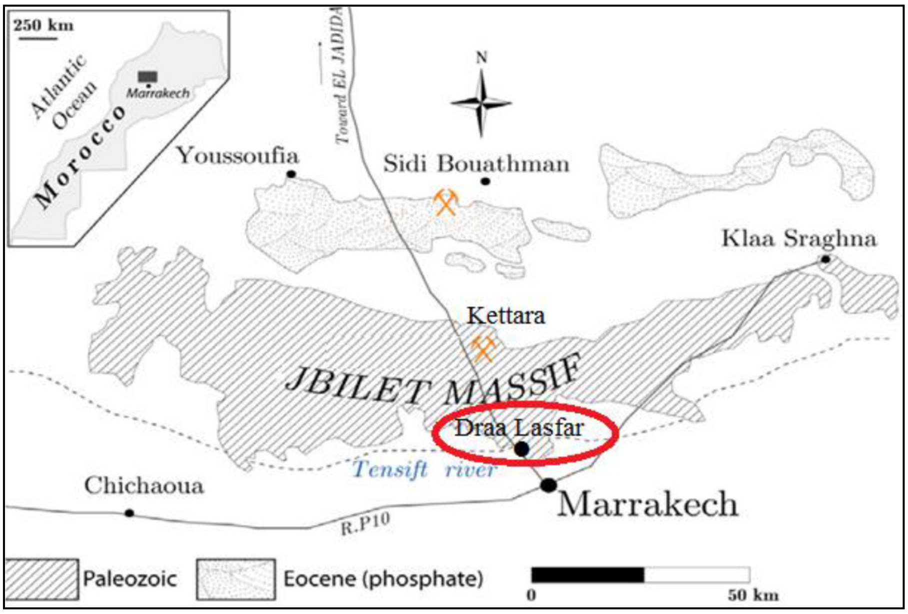

Fig. 1. Drâa Lasfar mine geographic situation in Marrakech region

Draa Lasfar mine is located a few hundred meters from the Tensift River, close to two rural communities: Tazakourte (V1) and Ouled Bou Aicha (V2) of about 5790 ha (Figure 2), 65% of this rural zone is occupied by farmland (Avila et al., 2012). The climate is Mediterranean, bordering arid and semi arid with an average annual precipitation of 231 mm (10 years). Temperatures are characterized by great daily and seasonal variation with an average value of 11.5°C in January and 36.8°C in July.

MATERIAL AND METHODS

In order to investigate the phytoavailability of metallic trace elements in the studied rural zone and to estimate the soil-plant by metallic trace elements relationship, soil and plant samples were taken from the two rural communities, Tazakourte (V1) and Ouled Bou Aicha (V2), located close to Draa Lasfar mine (Figure 2).

In each village, six sites have been designated to carry out soil sampling. For each site, five soil samples were taken inside a circle 50 cm in diameter at a depth between 0 and 20 cm. The mixture of all these samples, after homogenization in a plastic basin, constitutes the average sample of the village. The average soil sample of each village was crushed to dissociate the soil lumps and then sieved through a 2 mm nylon screen to remove large debris, gravel sized materials and plant roots (Yazdi and Narges, 2009). Only the smaller fraction than 2 mm was kept to determine total metallic trace elements (Cd, Cu, Pb and Zn).

Total heavy metal concentration in soil samples was determined by atomic absorption spectroscopy after an acid digestion of samples. The methodology followed for the digestion consisted in weighting 1g dry sample and adding 3 ml HNO3 (70%), 6 ml HCl (37%) and 3 ml HF (48%) (Yazdi and Narges, 2009). The analyzed sample was placed in a sand bath to complete the digestion. After digestion, the sample solution was air-cooled and then diluted with deionized water (Barkouch et al., 2015A). General soil properties (OM, pH, texture) were analyzed using standard methods (Giacalone et al., 2005). Soil chemical and physical properties of the samples are listed in Table 1.

Fig. 2. Geographical location of the Drâa Lasfar mine, Tensift River and the two rural communities

Plant samples of Couch Grass used as the main food for livestock and wheat as the main food for the human population living in this area were collected from the two rural communities. They were washed with deionized water and dried in an air-forced oven at 60°C for 48h. Different dry plant parts were ground in a stainless steel blender and passed through a 2-mm screen.

1 g of each plant part sample was ashed in a muffle furnace (T=550°C) for 4h (Avila et al., 2012). After cooling to ambient temperature, 1ml of HNO_3 was added, evaporated in a sand bath and put again into the muffle furnace (T=550°C). The procedures were repeated until the ash was white. It was finally dissolved in 5ml 5% HCl, transferred in a scaled 10 ml flask before analysis.

Quality Assurance: throughout the experimentation, pure deionized water was used, all chemicals were of reagent grade and all plastic ware soaked in 10% HNO3.

The contents of metallic trace elements in different soils and different plants parts are summarized in Tables 2, 3 and 4 respectively.

RESULTS AND DISCUSSIONS

Textural characteristics of the studied soils are shown in table 1 according to the classification of Shepard (Shepard and Moore, 1954).

These results showed that coarse sand (2.0-1.0 mm) and fine sand (MS 0.250-0.125 mm) were dominant fractions in all agricultural soils samples, with ranging from 25.3 to 27.7% and 23.4 to

Table 1. Mean values (%) of the grain-size analysis and geochemical characteristicsof different soils and tailings in Draa Lasfar region.

	V1 soil	V 2 soil	Mine Tailings	Background soil
Clay	25,3 ± 3,1	21,4 ± 2,1	1,2 ± 0,3	26,4 ± 2,5
Fine silt	16,5 ± 2,7	16,1 ± 1,7	4,6 ± 1,2	31,6 ± 3,7
Coarse silt	8,7 ± 1,5	9,2 ± 1,4	17,4 ± 1,2	20,1 ± 1,2
Fine sand	23,4 ± 3,1	25,2 ± 2,9	47,4 ± 3,7	5,2 ± 0,7
Coarse sand	25,3 ± 2,8	27,7 ± 2,5	27,4 ± 2,1	5,1 ± 0,4

Table 2. Geochemical characteristics of different soils and tailings in Draa Lasfar region.

	V1 soil	V 2 soil	Mine Tailings	Background soil
pH	7,8 ± 0,7	8,1 ± 0,6	2,9 ± 0,2	7,8 ± 0,2
E.C (ms/cm)	1,7 ± 0,4	1,5 ± 0, 4	7,2 ± 0,4	1,0 ± 0,2
CEC (meq/100g)	35,2 ± 2,7	31,6 ± 3,1	7,8 ± 1,6	16,4 ± 1,7
OM (%)	5,5 ± 0,7	4,7 ± 1,0	6,2 ± 1,7	4,3 ± 0,8
OC (%)	2,7 ± 0,4	2,2 ± 0,6	3,6 ± 1,0	1,5 ± 0,3
S %	1,7± 0,3	1,5± 0,4	3,7 ± 0,5	1,6 ± 0,4
Cl-	< 0,1	< 0,1	0,7 ± 0,1	< 0,1

Table 3. Mean concentrations of metallic trace elements in different soils in Draa Lasfar region.

Metals	V 1 soil	V 2 soil	Mine Tailings	Background soil
Cd (mg/kg)	2,2 ± 0,2	1,1 ± 0,7	143,1 ± 11,8	0,23 ± 0,04
Cu (mg/kg)	330,5 ± 22,8	227,8 ± 22,3	928,8 ± 88,5	40,7 ± 0,7
Pb (mg/kg)	255,3 ± 24,0	184,0 ± 27,1	3381,0 ± 507,1	11,8 ± 1,4
Zn (mg/kg)	890,5 ± 101,0	648,0 ± 174,3	2847,8 ± 460,3	133,9 ± 2,0

Table 4. Contamination factors and pollution index of different soils in Draa Lasfar region.

	Soil samples			
	Elements	V 1 soil	V 2 soil	Mine tailings
Contamination Factors	Cd	9,57	4,78	622,17
	Cu	8,12	5,60	22,82
	Pb	21,64	15,59	286,53
	Zn	6,65	4,84	21,27
Pollution Index		11,49	7,70	128,20

25.2% in V1 and V2 respectively. Clay (0.002 - 0.0063 mm) is represented with 25.3 to 21.4% in V1 and V2 respectively.

pH and EC are physicochemical soil characteristics that provide sufficient information to understand the soils capacity to retain heavy metal pollutants (De Matos et al., 2001). Numerical values on pH and EC for each analyzed sample are given in Table 2.

Results obtained for the soil pH measurements revealed that, in general, all sampled points presented slightly basic to neutral pH ranging from 7.2 to 8.1, similar to the background soil, but it was strongly acid in mining tailing sample with a pH 2.9.

EC showed more variability than the pH, with EC values ranging from 1.7 to 1.5 mS/cm in V1 and V2 respectively. These obtained values of EC are not significantly higher than those obtained for the background samples which indicate a similar salinity gradient. Mine tailings constitute a hot spot with an EC of 7.2 mS/cm. This high value is mainly due to high amounts of metals present in this sample (Barkouch et al., 2015B).

Many studies have mentioned that among factors influencing the accumulation of metals in soils, particle size played a significant role. Fine Grained soils often show higher concentrations of nutrients due to their greater surface-to-volume ratio and enrichment of organic matter (Wang et al., 2006).

Mean organic matter contents in studied soils (Table 2) were ranged from 5.5 in V1 to 4.7% dw in V2. These high values of organic content were due to agricultural activities in the vicinity of the mine.

The organic carbon content (OC) was ranged from 2.7% dw in V1 to 2.2 % dw in V2. This parameter increased in V1 soils corresponding probably to a decrease of the soil grain size. The highest organic carbon contents occurred at the soils that had the lowest sand contents and the highest silt and clay contents (Barkouch et al., 2015B).

Table 3 shows the results of total concentrations of four metallic trace elements (Cd, Cu, Pb and Zn) in soils and mine tailings. All the results are expressed in mg/kg.

As expected in most of the mines, the analyzed mine tailings had significantly higher metal concentrations than the two village soils ($p<0.05$). These tailings showed very high concentration of Cd (143,1 ± 11,8 mg kg-1), Cu (928,8 ± 88,5 mg kg-1), Pb (3381,0 ± 507,1 mg kg-1) and Zn (2847,8 ± 460,3 mg kg-1).

The adjacent village soils were also highly polluted by metals (Cd, Cu, Pb and Zn) and were significantly higher in V1 than V2 ($p<0.05$). . This finding corroborates the findings of many studies that found that almost all soil samples near mines were classified into polluted levels for Zn, Pb, Cu and Cd, particularly Zn and Pb (Zhu et al., 2020; Avila et al., 2012; Esshaimi et al., 2013; Barkouch et al., 2015A).

Total metal concentration showed significantly higher levels in V1 than V2 with 2,2 ± 0,2 mg/kg vs 1,1 ± 0,7 mg/kg for Cd, 330,5 ± 22,8mg/kg vs 227,8 ± 22,3mg/kg for Cu, 255,3 ± 24,0 mg/kg vs 184,0 ± 27,1 mg/kg for Pb and 890,5 ± 101,0 mg/kg vs 648,0 ± 174,3 mg/kg for Zn respectively.

Heavy metal concentrations in these soils are strongly determined by local geology or anthropogenic influences (Barkouch et al., 2015B). The weathering of minerals by the mining activity is one of the major natural sources of metals in soils of this region, while other anthropogenic sources including use of fertilizers and herbicides, irrigation and industrial effluents can accentuate metal pollution in this region. In this agricultural area, the Draa Lasfar abandoned mine tailings are likely to be one of the major sources of pollution (Barkouch et al., 2016).

The contamination factors (CF) (Table 4) serve to show the extent of the metallic contamination increase in this region. The pollution index (PI) is the arithmetic mean of the CF of analyzed metals (Gonçalves et al., 1992, 1994; Sanchez et al., 1994), and it allows an assessment of the degree of polymetallic pollution of analyzed soil samples. With a value greater than 1, it is an indication that the analyzed sample had a metallic contamination caused by human activities.

The PI (Table 4) showed that V1 and V2 soils have a high metal contamination because their PIs are well above the legal limit of pollution that is equal to 1.

The pollution index does not really express the potential hazardous effects generated on the environment and the public health (Zhu et al., 2020). This is because the critical characteristics of metallic trace elements, including mobility and toxicity are highly dependent on their specific chemical forms or availability (Yang et al., 2005). It is therefore necessary to determine the content of these metals in plants to assess correctly the potential threat to environmental health generated by these substances in soils.

Accumulation of metallic trace elements by plants is a complex phenomenon. It consists of several steps, such as: (a) adsorption and diffusion of metals through the plasma membrane of

Table 5. Enrichment factor of metallic trace elements in wheat and cough grass in V1 and V2.

Enrichment factor of elements		Cd		Cu		Pb		Zn	
		Root system	**Upper part**	**Root system**	**Upper part**	**Root system**	**Upper part**	**Root system**	**Upper part**
Cough grass	V1	1.40	0.55	0.09	0.04	0.40	0.04	3.46	0.84
	V2	1.41	0.80	0.12	0.05	0.51	0.05	3.09	0.91
Wheat	V1	1.27	0.80	0.10	0.02	0.05	0.02	1.22	0.75
	V2	2.03	0.77	0.09	0.02	0.06	0.02	1.12	0.58

Table 6. Element trace metallic concentrations in upper parts of plants in our study compared to several studies.

Plants	MTE concentration (mg/kg)				
	Cd	**Cu**	**Pb**	**Zn**	**Sources**
Wheat (V1)	1.7	7.1	4.82	670.7	Our study
Wheat (V2)	0.88	5.56	3.68	378.9	
Couch Grass(V1)	1.2	13.68	11.48	750.3	
Couch Grass(V2)	0.88	10.73	8.61	589.9	
Urtica dioica L.	0.65	9.71	2.77	*	(Kemaj et al., 2021)
Stellaria nemorum L.	*	5.6	10.9	48.1	(Wahsha et al., 2019)
Chaerophyllum hirsutum L.	*	8.8	*	50.2	(Wahsha et al., 2019)
wheat grains	0.10	5.38	0.38	25.24	(Maqbool et al., 2019)
Wheat grains	0.09	6.71	0.13	44.38	(Jihong et al., 2012)
Eucalyptus camaldulensis	0.24	10.63	6.54	49.21	(Al-Heety et al., 2021)
Ziziphus spina-christi	0.10	9.58	5.98	45.00	(Al-Heety et al., 2021)

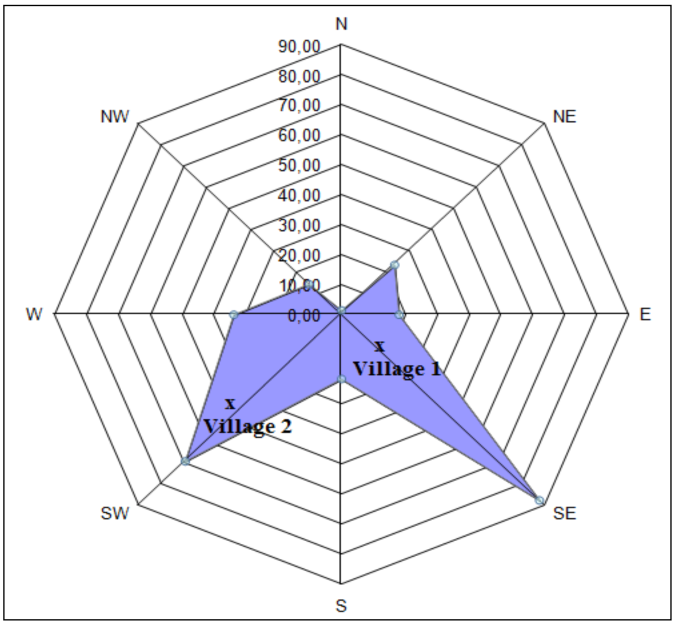

Fig. 3. Draa Lasfar district wind rose.

root cells; (b) xylem concentration and translocation; and (c) the capacity of neutralization of metals at the whole plant level and at the cellular level.

Results in Tables 7 and 8 showed that all studied plants could absorb and accumulate metals present in soils at different levels of concentrations. This finding can be justified by physiological response of plants to metallic trace elements presence in the soil (Boularbah et al., 2006). This response depends on the plant species, on the total concentration of metals in soil and on the bioavailability of the metal itself that depends on physico-chemical properties of soils, particularly the pH (Cuong and Obbard, 2006; Boularbah et al., 2006).

These results show significant difference of metals concentration in different plant parts ($p<0.05$) with higher metals concentration in roots. This MTE concentration increases with the duration of the flowering phase.

The highest values were obtained after eighth month in couch grass roots, where Pb reached 94,7mg/kg in village 1 vs 102.6mg/kg in village 2, Cd 1,6mg/kg in village 1 vs 3,1mg/kg in village 2, Cu 28,2mg/kg in village 1 vs 29.7mg/kg in village 2, Zn 2754.27mg/kg in village 1 vs 82.3mg/kg in village 2.

These results show clearly that couch grass could extract and accumulate more MTE from soil than wheat. This was probably related to the anatomical and biological characteristics of each plant species (Aikpokpodion et al., 2013), as well as their protective mechanisms (Dawson and Macklin, 1998). This result can also be justified by the low capacity of wheat roots to absorb MTE present in the soil due to their poorly developed root system unlike couch grass roots which have a more deeply penetrating and branched root system.

The results of metallic trace elements contents in wheat roots (Table 7) were roughly analogous in the two villages, but were significantly lower compared to those obtained in couch grass roots ($p<0.05$). Pb contents varied from 2.01 mg/kg in village 1 and 2.99 mg/kg in village 2 in the first month to11.2mg/kg and 13.9mg/kg in the eighth one, Cd from 0,3 and 0.4 mg/kg to 2,2 and 2.8mg/kg, Cu from 5,4 and 8.6 mg/kg to 23.8 and 28,7 mg/kg, and Zn from163,7 and 398.6 mg/kg to 725.5 and 1085,5 mg/kg.

To analyze the total metal concentration taken by plants from ground level, a term was used called bioconcentration factor (BCF), also termed as enrichment factor (EF). This factor

Table 7. Evolution of metallic trace elements concentration (mg/kg dry weight) in Couch Grass vegetative and reproductive organs during corps flowering stage.

Months		Cd		Cu		Pb		Zn	
		roots	leaves	roots	leaves	roots	leaves	roots	leaves
Nov	V1	0.50 ± 0.01	0.25 ± 0.01	10.74 ± 0.27	1.73 ± 0.04	8.43 ± 0.17	0.58 ± 008	589.40 ± 20.0	162.86 ± 1.7
	V2	0.41 ± 0.04	0.28 ± 0.02	7.86 ± 0.30	1.07 ± 0.19	5.73 ± 0.32	0.41 ± 0.07	370.99 ± 38.3	121.43 ± 7.1
Dec	V1	0.83 ± 0.05	0.42 ± 0.01	13.64 ± 0.34	2.20 ± 0.05	9.74 ± 0.14	0.72 ± 0.12	1098.44 ± 34.6	303.51 ± 2.8
	V2	0.66 ± 0.02	0.46 ± 0.01	10.16 ± 0.44	1.38 ± 0.28	6.00 ± 0.18	0.61 ± 0.11	534.60 ± 8.8	174.99 ± 1.7
Jan	V1	1.02 ± 0.09	0.52 ± 0.01	14.35 ± 0.44	2.31 ± 0.07	19.70 ± 0.29	1.38 ± 0.16	1370.01 ± 162.8	378.55 ± 13.3
	V2	0.67 ± 0.04	0.47 ± 0.02	12.04 ± 0.20	1.63 ± 0.13	16.01 ± 0.23	1.12 ± 0.23	722.22 ± 23.2	236.40 ± 4.3
Fev	V1	1.58 ± 0.15	0.93 ± 0.03	15.11 ± 0.57	5.37 ± 0.29	38.17 ± 1.66	3.96 ± 0.23	1558.02 ± 25.8	539.40 ± 73.6
	V2	0.75 ± 0.05	0.61 ± 0.02	13.00 ± 0.50	3.40 ± 0.36	37.88 ± 0.69	2.64 ± 0.24	978.02 ± 45.9	336.48 ± 11.7
Mars	V1	1.83 ± 0.03	0.71 ± 0.01	17.32 ± 1.03	7.99 ± 0.42	67.06 ± 1.39	4.64 ± 0.41	2016.88 ± 33.2	549.4 ± 135.7
	V2	1.08 ± 0.04	0.62 ± 0.02	14.47 ± 0.48	5.51 ± 0.43	51.84 ± 0.77	2.94 ± 0.33	1281.88 ± 67.0	245.31 ± 11.8
Apr	V1	2.06 ± 0.05	0.80 ± 0.03	19.25 ± 1.04	8.88 ± 0.43	78.17 ± 1.66	5.98 ± 0.44	2097.67 ± 18.7	571.43 ± 76.3
	V2	1.19 ± 0.08	0.68 ± 0.04	16.01 ± 0.22	6.09 ± 0.20	61.84 ± 0.97	4.26 ± 0.31	1443.68 ± 81.7	276.27 ± 14.4
Mai	V1	2.73 ± 0.05	1.07 ± 0.04	27.49 ± 1.72	12.69 ± 0.71	100.42 ± 2.16	9.12 ± 0.13	2824.74 ± 539.8	617.55 ± 19.1
	V2	1.33 ± 0.03	0.76 ± 0.02	24.04 ± 0.45	9.15 ± 0.41	92.59 ± 1.99	7.36 ± 0.47	2266.97 ± 54.7	540.56 ± 95.0
Jun	V1	3.07 ± 0.21	1.20 ± 0.10	29.65 ± 0.30	13.68 ± 0.26	102.64 ± 2.21	11.48 ± 0.29	3082.27 ± 236.1	750.29 ± 26.6
	V2	1.55 ± 0.81	0.88 ± 0.36	28.19 ± 0.38	10.73 ± 0.34	94.65 ± 1.20	8.61 ± 0.24	2754.27 ± 533.0	589.85 ± 41.6

Table 8. Evolution of metallic trace elements concentration (mg/kg dry weight) in wheat vegetative and reproductive organs during corps flowering stage.

Months		Cd		Cu		Pb		Zn	
		roots	seeds	roots	seeds	roots	seeds	roots	seeds
Nov	V1	0.44 ± 0.01	0.26 ± 0.01	8.59 ± 1.07	3.12 ± 0.23	2.99 ± 0.03	0.45 ± 0.01	398.56 ± 86.45	157.50 ± 45.23
	V2	0.28 ± 0.03	0.18 ± 0.01	5.35 ± 0.23	1.54 ± 0.02	2.01 ± 0.03	0.03 ± 0.01	163.75 ± 27.28	148.63 ± 21.40
Dec	V1	0.80 ± 0.07	0.47 ± 0.06	10.18 ± 1.00	3.70 ± 0.22	4.97 ± 0.36	0.85 ± 0.05	548.72 ± 65.42	253.32 ± 15.26
	V2	0.66 ± 0.03	0.42 ± 0.01	6.96 ± 0.74	2.01 ± 0.05	3.20 ± 0.08	0.35 ± 0.03	319.57 ± 59.77	288.83 ± 46.88
Jan	V1	1.17 ± 0.06	0.58 ± 0.17	12.62 ± 0.24	4.62 ± 0.07	6.94 ± 0.08	0.84 ± 0.08	812.27 ± 27.37	365.33 ± 44.51
	V2	1.05 ± 0.03	0.44 ± 0.01	8.75 ± 0.06	2.84 ± 0.02	3.23 ± 0.16	0.52 ± 0.01	457.27 ± 19.58	271.41 ± 28.39
Fev	V1	1.60 ± 0.06	0.79 ± 0.06	18.51 ± 0.62	5.64 ± 0.01	9.83 ± 0.68	2.12 ± 0.08	780.17 ± 23.14	432.95 ± 29.35
	V2	1.22 ± 0.02	0.47 ± 0.07	15.81 ± 0.40	3.02 ± 0.01	7.81 ± 0.25	1.03 ± 0.01	492.27 ± 34.00	366.78 ± 17.15
Mars	V1	1.75 ± 0.04	0.93 ± 0.05	21.50 ± 0.75	6.17 ± 0.06	11.93 ± 0.13	2.60 ± 0.32	918.32 ± 68.10	522.61 ± 55.88
	V2	1.45 ± 0.03	0.58 ± 0.17	17.01 ± 0.33	3.09 ± 0.09	8.54 ± 0.14	1.11 ± 0.01	591.99 ± 53.07	224.15 ± 19.21
Apr	V1	1.93 ± 0.04	1.18 ± 0.04	21.93 ± 0.82	6.58 ± 0.06	11.60 ± 0.11	2.62 ± 0.01	970.19 ± 18.97	598.11 ± 34.85
	V2	1.70 ± 0.03	0.60 ± 0.06	17.74 ± 0.86	4.15 ± 0.03	9.36 ± 0.09	2.00 ± 0.01	658.02 ± 7.21	290.00 ± 42.43
Mai	V1	2.19 ± 0.05	1.40 ± 0.02	23.48 ± 0.31	6.69 ± 0.12	12.51 ± 0.29	3.87 ± 0.53	1016.22 ± 31.14	624.21 ± 20.28
	V2	1.78 ± 0.04	0.83 ± 0.04	18.95 ± 0.48	5.23 ± 0.36	10.89 ± 0.39	2.94 ± 0.06	693.99 ± 85.22	332.62 ± 38.87
Jun	V1	2.79 ± 0.06	1.70 ± 0.08	28.72 ± 0.97	7.10 ± 0.54	13.92 ± 0.13	4.82 ± 0.58	1085.47± 133.29	670.72 ± 44.88
	V2	2.23 ± 0.19	0.88 ± 0.05	23.79 ± 0.46	5.56 ± 1.30	11.22 ± 0.11	3.68 ± 0.59	725.54 ± 31.14	378.90 ± 15.45

represents the ratio of metal concentration DW in the plant to the metal concentration DW in the soil. BCF is an indication of the magnification of contaminants from a lower to a higher trophic level.

BCF is expressed as (Dowdy and Mc-Kone, 1997; Santillan et al., 2010):

BCF= Metal in Whole plant DW / Metal in soil DW.

For plants, the BCF can be used to assess the metal accumulation efficiency, whereby value greater than 1 is an indication of plants potential to bioaccumulate pollutant from soil (Zhang et al., 2002; Santillan et al., 2010).

The calculation of the enrichment factor stresses which pollutant contributes the most to pollution at each plant.

On the other hand, results show that trace elements levels in the plants' upper parts were significantly lower compared to the root system ($p<0.05$), which proved that metallic trace elements movement along the plants conductive system was strongly limited (Aikpokpodion et al., 2013; Sahuquillo et al., 2003). These upper parts concentrations were abnormally higher than those found in leaves of some plants growing under the same conditions. Table 5 summaries the difference between element trace metallic leaves' concentrations in our study compared to several studies (Kemaj et al., 2021; Bihong et al., 2021; Al-Heety et al., 2021; Maqbool et al., 2019; Wahsha et al., 2019; Jihong et al., 2012).

This high accumulation of metallic trace elements in the upper part of plants was probably due to the fact that they were exposed to the dominant wind directions which favor the dispersion of metal pollutants on their surface and consequently their absorption by the leaves.

The study of the wind rose of Marrakech city (Figure 3) can be used to justify the dispersion of metallic trace elements and consequently the increase of their concentrations obtained in leaves. Strictly defined, the wind rose denotes a class of diagrams designed to display the distribution of wind direction experienced at a given location over a period of time.

The elaboration of the wind rose shows that the south-west and south-east directions of the winds are dominant and that the relative frequency of the wind speed covers the sampling site of the two villages in the vicinity of the Draa Lasfar mine. This result explains the crucial role of winds as the main factor of transport and dispersion of metallic elements on plant surfaces in this region.

CONCLUSION

Mining activity and related industry can increase MTE concentrations in soil, couch grass and wheat, thereby posing human health risk through food ingestion. In this study, samples of soil, wheat (main food for the human population) and couch grass (main food for livestock) were collected from Draa Lasfar mine region northwest Marrakech - Morroco. Four kinds of MTEs Cd, Cu, Pb and Zn were studied for their spatial distribution in two rural villages' soils in the vicinity of the Draa Lasfar mine, in couch grass, in wheat and enrichment in different plants organs (roots, leaf or grains). Results show that the spatial distribution of MTEs in couch grass and wheat' roots were higher than upper parts and likely linked to mining activity. Most of MTEs enrichment in upper organs of couch grass and wheat were higher compared to other studies, indicating that MTEs were accumulated from atmospheric dust. The study of the wind rose justified the dispersion of MTEs and the increase of their concentrations obtained in the upper parts.

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The present research did not receive any financial support.

CONFLICT OF INTEREST

The authors 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, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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