DOI: 10.22620/agrisci.2018.23.008

HEAVY METAL CONTENT IN DANDELION (*TARAXACUM OFFICINALE* WEB.)

Violina Angelova*, Krasimir Ivanov

Agricultural University – Plovdiv

***E-mail: vileriz@abv.bg**

Abstract

A comparative research has been carried out to allow us to determine the quantities and the central points of accumulation of Pb, Zn and Cd in the vegetative organs of dandelion (*Taraxacum officinale* Web.), as well as to ascertain the possibilities of using dandelion as an indicator plant. The dandelion plants were collected from four selected sites with different anthropogenic activity in Plovdiv and the region of Plovdiv, Bulgaria. The contents of heavy metals in the plant material (roots, stems, leaves, and blossoms) were determined by the method of the microwave mineralization. To determine the heavy metal content in the samples, ICP was used. The distribution of heavy metals in the plant organs of *Taraxacum officinale* depends on the total content and quantity of available forms of the heavy metal in the soil. The number of metals measured in soils and plants corresponded with the contamination load of the sampling place. The highest values of metals were found in the soil and plants sampled at a 0.1 km and 0.5 km distance from the source of pollution - the Non-Ferrous Metal Works (KCM) near Plovdiv, Bulgaria.

The lead and zinc translocation factors were greater than 1, whereas for cadmium it was less than 1. A clearly distinguished trend exists which describes the accumulation of heavy metals within the vegetative organs of the dandelion. The depots for accumulation were in the following order: for Pb and Zn: leaves >roots > blossoms > stems, and for Cd: roots >leaves > blossoms > stems. Higher Cd content was found in the underground part of the plants, indicating soil contamination. As the level of contamination increased, the potential of dandelion to uptake and accumulate Cd in the aerial parts of the plant increased. The higher Pb and Zn content in the leaves rather than in the roots in all locations illustrated a contribution of significant atmospheric deposition. The content of heavy metals both in the dandelion plant tissue and in the soil should be seen as a good indicator of environmental pollution.

Keywords: distribution, heavy metals, *Taraxacum officinale,* translation factor, uptake.

INTRODUCTION

Dandelion, also known as *Taraxacum officinale*, is a genus of herbaceous perennial plants. The dandelion is characterized by a high relative factor of accumulation of some pollutants. It is used for assessing the environment for pollution with SO_2, polycyclic aromatic hydrocarbons and heavy metals (Maleci et al., 2014). The dandelion meets all criteria adopted for indicator plants: very common all over the world and easy for identifying, easily adapted to various geomorphic, pedologic and climatic conditions; it is characterized with relatively high tolerability toward the environmental pollutants (Królak, 2003; Zupan et al., 2003; Rosselli et al. 2006), it shows correlation between the level of pollution with the element in the environment (air, soil) and its content in the parts of the plant. The dandelion has been used in a series of regional large-scale studies about bio-monitoring of the environmental pollution in Bulgaria (Djingova and Kuleff, 1999), Poland (Kabata-Pendias and Dudka, 1991), Hungary (Kovac et al., 1993), USA (Keane et al., 2001), Germany (Winter et al., 1999) and Canada (Marr et al., 1999). The content of metals in the leaves of dandelion is related with the environmental pollution, which has been established in previous studies (Djingova and Kuleff, 1993; Kabata-Pendias and Dudka, 1991; Marr et al., 1999; Keane et al., 2001). Despite that, the relation between the content of metals in the plant tissues (leaves and roots) and the environment (soil and air) has not been completely cleared until now, due to the different and even contradictory results.

The purpose of this study is to research the entrance and distribution of heavy metals in the dandelion, as well as the possibilities for using the dandelion as an indicator plant in evaluating the pollution of the soils.

MATERIALS AND METHODS

Dandelion was used as a test plant. The samples were picked from 4 places characterized by various degree and type of pollution. The first two grounds have soil and aerosol pollution, the third one is from a region with intensive traffic, and the fourth one is a control sample. The first two grounds are situated near the KCM (Non-Ferrous Metals Factory) – Plovdiv (at a distance of 0.1 km and 0.5 km), the third ground is from the grasslands at Mendeleev Blvd. (a boulevard with intensive traffic) and the fourth ground is from the park of the Agricultural University – Plovdiv (control sample).

The soil samples were prepared for analysis by treatment with aqua regia (ISO 11466). The mobilisable heavy metals contents in soils, considered as a “potentially bioavailable metal fraction”, were extracted by a solution of DTPA (1 M NH_4HCO_3 and 0.005 M DTPA, pH 7.8) (Soltanpour and Schwab, 1977). The content of heavy metals in the soils and plant samples in the vegetative parts of the dandelion (roots, stems, leaves and blossoms) was determined in the microwave mineralization method. ICP Prodigy 7 was used for determining the content of heavy metals in the samples.

RESULTS AND DISCUSSION

The total content of Zn, Pb and Cd in the soils at a distance of 0.1 and 0.5 km from the KCM is extremely high and it exceeds the maximum concentration limits (MPC) (Table 1). In the soils from point 3, only the content of lead is slightly above the permissible concentrations. The results for the mobile forms of the metals extracted by DTPA show that the mobile forms of Cd in the contaminated soils are the most significant portion of its total content and range from 63.0 to 64.0%, followed by Pb with 41.7 to 45.7% and Zn with 11.5 to 11.8%.

The absorption of metals by the plants depends on many factors such as the content of elements in the soil and the ability of the plant to uptake the metals (Gambus, 1997). Significant differences were established in the uptake of metals in the different parts of the dandelions grown on polluted and on unpolluted soils. A big part of all three elements is accumulated in the root system and the quantity depends above all on the content of heavy metals in the soil.

The content of Pb in the root system of the dandelion picked at a distance of 0.1 and 0.5 km from the KCM varies from 50.8 to 95.0 $mg.kg^{-1}$, Zn – from 41.9 to 109.3 $mg.kg^{-1}$ and Cd – from 9.97 to 15.5 $mg.kg^{-1}$ (Fig. 1). Significantly lower values were established in the dandelion picked from point 3 – 1.0 $mg.kg^{-1}$ Pb, 6.8 $mg.kg^{-1}$ Zn and 0.5 $mg.kg^{-1}$ Cd. The results obtained about the dandelion from point 4 (the park) are also similar.

Table 1. Content of total and DTPA- extractable Pb, Cd and Zn ($mg.kg^{-1}$) in soils

Parameter	Soil 1 (S1) 0.1 km from KCM		Soil 2 (S2) 0.5 km from KCM		Soil 3 (S3) Mendeleev boulevard		Soil 4 (S4) control	
	Total	DTPA	Total	DTPA	Total	DTPA	Total	DTPA
Pb	2509.1	1044.5	1983.5	942.2	142.9	32.8	55.9	19.5
Cd	63.7	40.8	50.1	31.6	1.7	0.55	0.58	0.15
Zn	2423.9	287.1	2029.0	233.3	154.0	18.1	145.5	15.1

MPC (pH 6.0-7.4) – Pb -60 $mg.kg^{-1}$, Cd-2.0 $mg.kg^{-1}$, Zn-320 $mg.kg^{-1}$

The moving and accumulation of heavy metals in the vegetative parts of the dandelion are significantly different.

The content of heavy metals in the stems is significantly lower in comparison with the root system, which shows that their moving along the vascular system is highly restricted. In the stems of the dandelion form point 1 and point 2 (0.1 and 0.5 km from the KCM) the content of Pb varies from 9.9 to 11.4 $mg.kg^{-1}$, Zn from 10.7 to 14.2 $mg.kg^{-1}$ and Cd from 1.3 to 1.5 $mg.kg^{-1}$, while in point 3 (with intensive traffic) the content of Pb reaches 0.15 $mg.kg^{-1}$, Zn –5.6 $mg.kg^{-1}$ and Cd – 0.1 $mg.kg^{-1}$. The values of the control sample dandelion are insignificantly lower (Fig. 1).

The content of heavy metals in the leaves of the dandelion is the highest in comparison with the root system and the stems. In the leaves of the dandelion (0.1 and 0.5 km from the KCM), the content of Pb varies from 113.2 to 252.6 $mg.kg^{-1}$, Zn – from 89.2 to 179.3 $mg.kg^{-1}$ and Cd - from 6.61 to 10.1 $mg.kg^{-1}$, while in point 3 the content of Pb reaches 2.97 $mg.kg^{-1}$, Zn –13.95 $mg.kg^{-1}$ и Cd – 0.3 $mg.kg^{-1}$. The values of the control sample dandelion are insignificantly lower (Fig. 1).

Similar results were established also by Maleci et al. (2014) and Kleckerová and Dočekalová (2014), according to who the content of heavy metals is higher in the leaves of the dandelion in comparison with the roots.

This shows the ability of this plant to transfer the metals from the roots to the leaves, which defines the dandelion as an indicator plant, according to Baker (1981). According to Krolak (2003), Kabata Pendias and Krakowiak (1997), and Zeidler (2005), the content of Pb in the leaves of the dandelion is higher than in the roots, both in unpolluted and polluted areas.

Similar results were established also by Maleci et al. (2014), according to whom in polluted places the dandelion can accumulate Cd in much higher concentrations than in unpolluted places, and above the level of toxicity, indicated by Kabata-Pendias (2011).

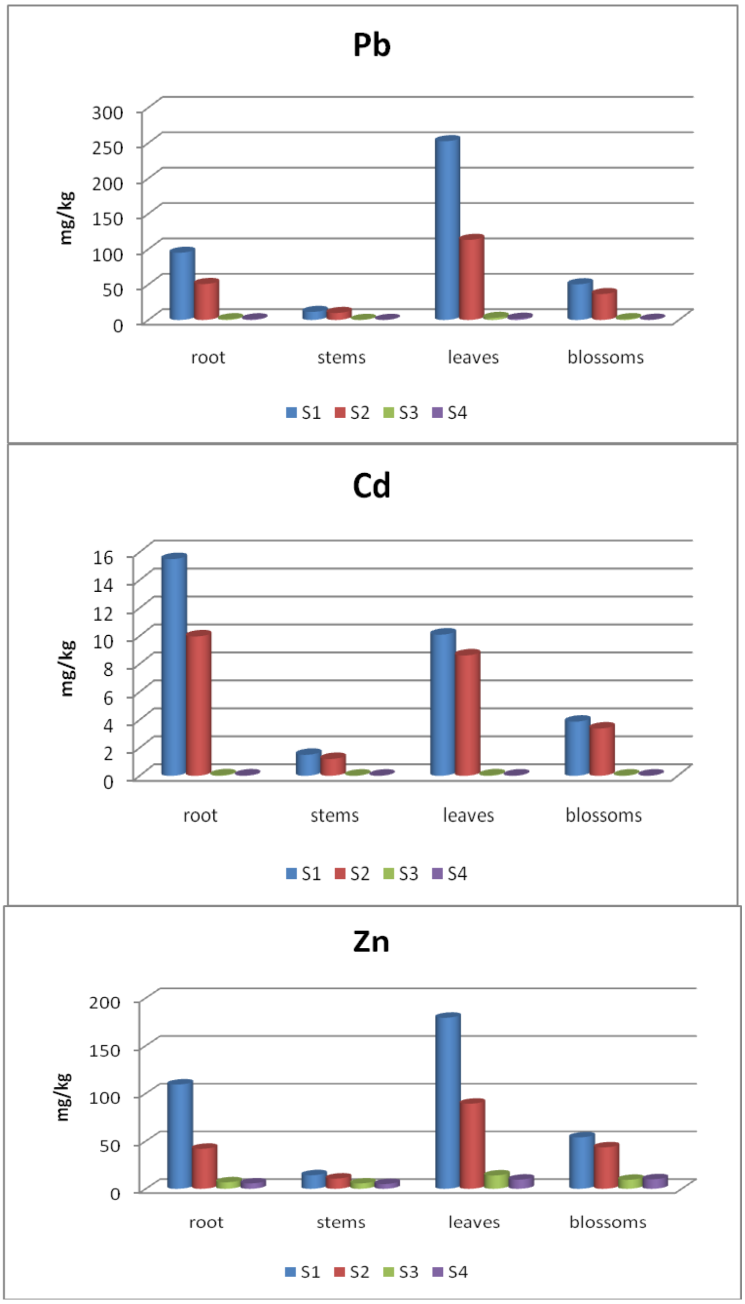

Fig. 1. *Content of Pb, Cd and Zn (mg.kg^{-1}) in vegetative parts of dandelion*

The content of heavy metals in the blossoms of the dandelion is lower than in the root system. In the blossoms of the dandelion (0.1 and 0.5 km from the KCM), the content of Pb varies from 36.6 to 50.4 mg.kg^{-1}, Zn – from 43.4 to 53.9 mg.kg^{-1} and Cd from 3.38 to 3.87 mg.kg^{-1}, while in point 3 the content of Pb reaches 1.17 mg.kg^{-1}, Zn – 9.98 mg.kg^{-1} and Cd – 0.1 mg.kg^{-1}. The content of Pb is the lowest in the blossoms of the dandelion from point 4 (0.32 mg/kg). No significant differences are noticed in relation to Zn and Cd.

Kabata Pendias and Dudka (1991), take the background values for the content of the elements in the leaves of the dandelion: for Zn 20-110 mg.kg^{-1}, Pb 1.6-6.5 mg.kg^{-1} and Cd 0.3–1 mg.kg^{-1}; while in the roots of the dandelion it is as follows: for Zn 10–60 mg.kg^{-1}, Pb 0.2–5.0 mg.kg^{-1} and Cd 0.1–1.0 mg.kg^{-1}.

The comparison of the results obtained by us about the dandelion from point 3 and 4 with the values given above shows that the content of heavy metals in the roots and stems are within the proposed background values. The content of all tested metals in the plants significantly exceeds the background values in the samples picked from point 1 and point 2.

The results obtained by us show that the accumulation of metals in the leaves is proportional to the content of heavy metals in the soil and the highest is the content of metals in the dandelion from the highly polluted soils (point 1 and point 2).

A significant difference between the content of metals in the leaves and roots is observed among the samples picked from unpolluted and polluted regions.

The distribution of heavy metals in dandelion has a selective character, which is specific to the individual elements. The main part of Pb and Zn accumulate in the aboveground mass of the dandelion, while in cadmium – in the root system (Fig. 2).

The translocation factor ($TF=C_{shoots}/C_{roots}$) and the bioaccumulation factors ($BF_{roots}=C_{roots}/C_{soil}$ and $BF_{leaves}=C_{leaves}/C_{soil}$) were calculated in order to be able to give a firm answer to the question what are the abilities of the dandelion to extract heavy metals from the soil, and in order the potential of the dandelion as an indicator plant to be assessed.

The obtained results about the translocation and bioaccumulation factors for studying the metals are presented in Table 2.

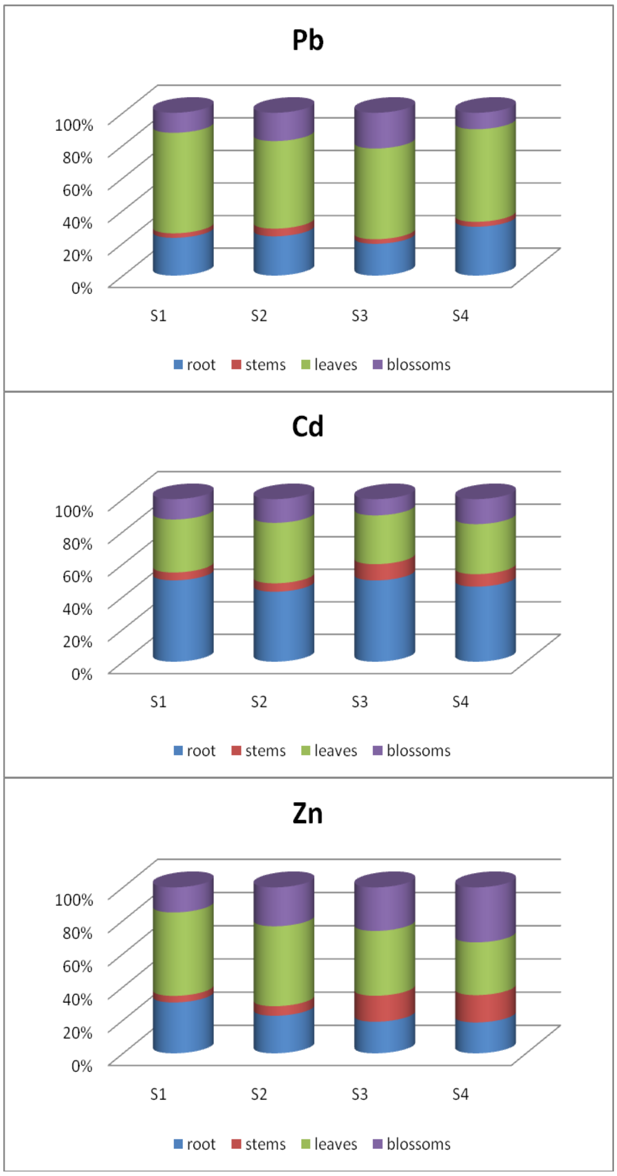

***Fig. 2**. Distribution of Pb, Cd and Zn in dandelion*

Table 2. Translacation factor (TF) and bioaccumulation factors (BF)

Element	Factor	Soil 1 (S1)	Soil 2 (S2)	Soil 3 (S3)	Soil 4 (S4)
Pb	TF	2.78	2.42	3.0	2.0
	BF_{roots}	0.04	0.03	0.007	0.02
	BF_{leaves}	0.11	0.06	0.02	0.03
Cd	TF	0.75	0.98	0.80	0.83
	BF_{roots}	0.24	0.20	0.29	0.52
	BF_{leaves}	0.18	0.20	0.24	0.43
Zn	TF	1.77	2.38	2.88	2.59
	BF_{roots}	0.05	0.02	0.04	0.04
	BF_{leaves}	0.08	0.05	0.13	0.10

$TF = C_{shoots}/C_{roots}$; $BF_{roots} = C_{roots}/C_{soil}$; $BF_{leaves} = C_{leaves}/C_{soil}$

The transfer factor (TF) gives information about the ability of plants to absorb heavy metals through the roots and to transfer them to the haulms (the leaves). The results obtained by us show that the translocation factor for Pb and Zn is higher than 1, while for Cd it is lower than 1. The higher the level of pollution gets, the higher the potential of the dandelion to absorb and accumulate Cd in the plant haulms becomes.

The translocation factor for Pb is the highest in the dandelion from the places with intensive traffic (3.0). The values for the dandelion from the region of the KCM – Plovdiv (2.42–2.78) are insignificantly lower and they are the lowest in the control sample dandelion (2.0). In relation to Zn, no significant differences are noticed in the values of the factor in the dandelion from the polluted and unpolluted soils (2.38-2.88), except in point 1 where it is the lowest (1.77).

The results obtained by us are in conformity with the findings of Kleckerová and Dočekalová (2014), who established accumulation of Cd in the roots and Pb in the leaves. According to Maleci et al. (2014) and Malik et al. (2010), TF is > 1, which shows that *T. (officinale* has the ability to accumulate metals.

The bioaccumulation factor (BF) is assessed in order to determine the relative absorption of metals by the plants in relation to the soil. According to Kleckerová and Dočekalová (2014), the higher BCF of Cd than that of Pb confirms a higher level of accessibility of Cd, which is confirmed by our results as well.

According to Kabata-Pendias and Pendias's (1999) BF leaves/soil for Pb have a higher value than BF roots/soil, and unlike Cd, it is accumulated primarily in the leaves, which is confirmed by our results as well. Kastori et al. (1992) established high mobility of Zn and its absorption by the roots of the plants.

The studies conducted by Krolak (2003) prove that the inhibition of the absorption of Zn by a dandelion happens when the soils are highly polluted with metals. According to the author, the significant reduction of the accumulation of Zn in the leaves and the root of the dandelion is related to the increase of the content of Zn in the soil.

This is confirmed by the values of BF leaves/soil and BF roots/soil. In the dandelion from highly polluted soils (point 1 and point 2) the coefficients vary from 0.05 to 0.08 in leaves/soil and from 0.02 to 0.05 in roots/soil.

In the control sample and in the boulevard with intensive traffic, the BF leaves/soil are significantly higher and they reach values respectively up to 0.10 and 0.13.

The values of Pb for the accumulation factor (root/soil) vary from 0.007 to 0.04 and leaves/soil vary from 0.02 to 0.11. Pb is relatively static in the soil and, therefore, less accessible for absorption by plants. Pb is relatively poorly absorbed by the dandelion.

The accumulation factor root/soil, as well as leaves/soil for this element in all analysed dandelion samples, are significantly lower than 1. According to Krolak (2003), Cd and Pb are absorbed by the dandelion, even from soils highly polluted with these elements. According to Kabata Pendias and Pendias (1999), there is a connection between the concentration of Pb in the plants and its concentration in the soils.

The excessive accumulation of Pb is explained by the weakening of the biological barrier leading to non-selective absorption of the element. The higher the concentration of Pb in the soil solution becomes, the higher its quantity in the plants gets, especially in the roots of the dandelion and, to a lesser extent, in the haulms.

Kabata Pendias and Pendias (1999) also show that in excessive accumulation of Pb, the absorption of Cu and Zn by the plant's decreases, while the absorption of Cd may increase. This additional influence of Pb on Cd absorption can be in result of a damage of the membrane cells.

The values of the accumulation coefficient for Cd root/soil vary from 0.18 to 0.52, while in leaves/soil they vary from 0.20 to 0.43. The results obtained by us show that the dandelion is a good indicator of the level of Cd in the environment, which complies with the results of Kabata-Pendias and Krakowiak (1997).

CONCLUSIONS

1. On the basis of the results obtained, it can be concluded that the accumulation of heavy metals in *Taraxacum Officinale's* plant organs depends on the total content and amount of available forms of heavy metals in the soil.

2. There is a pronounced trend in the accumulation of heavy metals in the dandelions vegetative organs. In the underground part of the plants, a higher content of Cd is found indicating soil contamination. The higher content of Pb and Zn in the dandelion leaves shows a significant aerosol deposition.

3. The results obtained for the heavy metals content in the dandelion vegetative organs and soils confirm that dandelion can be used as an indicator of the contamination of Cd in the environment.

Acknowledgement

This work is supported by the Bulgarian Ministry of Education, Project DFNI 04/9.

REFERENCES

Baker, A. J. M., 1981. Accumulators and excluders strategies in the response of plants to heavy metals. Journal of Plant Nutrition, 3: 643–654.

Djingova, R., I. Kuleff, 1993. Monitoring of heavy metal pollution by *Taraxacum officinale*. - In: B. Markert (Editor), Plants as Biomonitors. Indicators for Heavy Metals in Terrestrial Environment, New York, NY: VCH: p. 435.

Djingova, R., I. Kuleff, 1999. Seasonal variations in the metal concentration of *Taraxacum officinale, Plantago major* and *Plantago lanceolata*. Chemistry and Ecology, 16: 239–253.

Gambuś, F., 1997. Pobieranie metali ciężkich przez różne gatunki roślin uprawnych. Część II. Akumulacja metali ciężkich przez rośliny. Acta Agraria, Series Agraria, 35: 21–29.

ISO 11466, 1995. Soil quality - Extraction of trace elements soluble in aqua regia.

Kabata-Pendias, A., 2011. Trace elements in soils and plants, 3rd edn. CRC, Boca Raton, p. 365.

Kabata-Pendias, A., A. Krakowiak, 1997. Useful photo indicator (dandelion) for trace metals pollution. In: A.W. Andren, and T.W. Bober (Editors), (Proceeding of 5th Intern. Conf. Proc. Transport, Fate and Effects of Silver in the Environment, Madison, Wisc.), pp. 145–149.

Kabata-Pendias, A., H. Pendias, 1999. Biogeochemia pierwiastków śladowych. Wyd. Naukowe, PWN, Warszawa.

Kabata-Pendias, A., S. Dudka, 1991. Trace metal contents of *Taraxacum officinale* (dandelion) as a convenient environmental indicator*.* Environmental Geochemical Health, 13:108–113.

Kastori, R., M. Petrovic, N. Petrovic, 1992. Effect of excess Pb, Cd, Cu and Zn on water relations in sunflower. Journal of Plant Nutrition, 15: 2427–2429.

Keane, B., M. H. Collier, J. R. Shann, S. H. Rogstad, 2001. Metal content of dandelion *(Taraxacum officinale)* leaves in relation to soil contamination and airborne particulate matter. Science of the Total Environment, 281: 63–78.

Kleckerová, A., H. Dočekalová, 2014. Dandelion plants as a biomonitor of urban area contamination by heavy metals. International Journal Environmental Research, 8 (1):157–164.

Kovac, P., G. Turcsanyi, K. Penksza, L. Kaszab, P. Szöke, 1993. Heavy metal accumulation by ruderal and cultivated plants in a heavily polluted district of Budapest. In: B. Markert (Editor), Plants as Biomonitors – Indicators for Heavy Metal in Terrestrial Environment. VCH, Weinheim, pp. 495–505.

Królak, E., 2003. Accumulation of Zn, Cu, Pb and Cd by dandelion *(Taraxacum officinale* Web.*)* in environments with various degrees of metallic contamination. Polish Journal of Environmental Studies, 12 (6): 713–721.

Maleci, I., G. Buffa, M. Wahsha, C. Bini, 2014. Morphological changes induced by heavy metals in dandelion *(Taraxacum officinale Web.)* growing on mine soils. Journal Soils and Sediments, 14: 731–743.

Malik, R. N., S. Z. Husain, I. Nazir, 2010. Heavy metal contamination and accumulation in soil and wild plant species from industrial area of Islamabad, Pakistan. Journal of Botany, 42 (1): 291–301.

Marr, K., H. Fyles, W. Hendershot, 1999. Trace metals in Montreal urban soils and the leaves of *Taraxacum officinale.* Canadian Journal Soil Science, 79: 385–387.

Rosselli, W., M. Rossi, I. Sasu, 2006. Cd, Cu and Zn contents in the leaves of *Taraxacum officinale*. Forest Snow and Landscape Research, 80 (3): 361–366.

Soltanpour, P. N., A. P. Schwab, 1977. A new soil test of macro- and micro-nutrients in alkaline soils. Commun. Soil Sci. Plant Analysis, 8: 195–207.

Winter, S., O. Wappelhorst, U.S. Leffler, S. Korhammer, B. Markert, 1999. Biomonitoring in Städten mit *Taraxacum officinale* Web. (Loewenzahn) – Eine Studie in der Stadt Zittau, Sachsen. – In: J. Oehlmann, and B. Markert (Editors), Ökotoxicologie/Ökosystemare Ansätze und Methoden, pp. 238–247.

Zeidler, M., 2005. Heavy metals in two herb species river Morava, Czech Republic. Polish Journal of Ecology, vol. 53 (2): 185–195.

Zupan, M., T. Kralj, H. Grcman, V. Hudnik, F. Lobnik, 2003. The accumulation of Cd, Zn, Pb in *Taraxacum officinale* and *Plantago lanceolata* from contaminated soils. Proc VII ICOBTE, Uppsala Sv.