Electronic Journal of Polish Agricultural Universities is the very first Polish scientific journal published exclusively on the Internet, founded on January 1, 1998 by the following agricultural universities and higher schools of agriculture: University of Technology and Agriculture of Bydgoszcz, Agricultural University of Cracow, Agricultural University of Lublin, Agricultural University of Poznan, Higher School of Agriculture and Teacher Training Siedlce, Agricultural University of Szczecin, and Agricultural University of Wroclaw.

ELECTRONIC
JOURNAL
OF POLISH
AGRICULTURAL
UNIVERSITIES

2001
Volume 4
Issue 1
Series
ENVIRONMENTAL DEVELOPMENT

KRÓLAK E. 2001. HEAVY METAL CONTENT IN FALLING DUSTS, SOIL AND DANDELION (*TARAXACUM OFFICINALE* WEBB.) IN SOUTHERN PODLASIE LOWLAND **Electronic Journal of Polish Agricultural Universities**, Environmental Development, Volume 4, Issue 1.
Available Online http://www.ejpau.media.pl

HEAVY METAL CONTENT IN FALLING DUSTS, SOIL AND DANDELION (*TARAXACUM OFFICINALE* WEBB.) IN SOUTHERN PODLASIE LOWLAND

Elżbieta Królak
Department of Ecology and Environmental Protection, University of Podlasie, Siedlce, Poland

ABSTRACT

The concentration levels of the following metals: Cd, Pb, Zn, Mn, Fe and Ni in falling dusts, soil and dandelion (*Taraxacum officinale* Webb.) were examined in selected areas of Southern Podlasie Lowland. The research was conducted from 1995 to 1999. The metals were marked by means of the AAS technique. The deposition of Cd and Pb metals did not exceed the values standardized in the Polish legislation, and the mean metal concentration in the soil was the same as the natural content. The mean metal concentration in dandelion leaves and root was within the values accepted as background in professional literature. It was proved that in agricultural lands that

PRINT

were not excessively loaded with heavy metals, the metal level in the root of the plant is of higher significance than in the leaves when using dandelion for bio-indicatory purposes.

Key words: Southern Podlasie Lowland, heavy metals, falling dusts, soil, dandelion (*Taraxacum officinale* Webb.), enrichment coefficients, bio-indication.

INTRODUCTION

In agricultural lands of Poland, the evaluation of environment pollution with heavy metals in the aspect of falling dusts, soil and plants is hardly ever conducted. According to the norms currently in force, the maximum allowed deposition of Pb and Cd is specified in falling dusts (Appendix 1998). According to the recommendations of IUNG in Puławy, when determining the degree of soil pollution with heavy metals, Cu, Ni and Zn are also taken into consideration [16]. Plants are frequently used when estimating the degree of environment pollution with heavy metals [4,34,10,20,30,15,29,6]. Plants are able to absorb and cumulate substantial amounts of metals in their tissues with no visible physiological effects. The plants used for the purposes of bio-monitoring are those occurring commonly and numerously in the scale of the region and even the continent, and are characterized by the ability to cumulate metals in the leaves and root. The dandelion (*Taraxacum officinale* Webb.), among other plants, is used as an indicatory plant [18,32,33,3,8]. Professional literature indicates the range of the metal content in dandelion growing in a non-polluted environment and accepted as the background [18,32].

It is commonly known that heavy metals constitute a serious hazard for organisms. They move easily in trophic chains and can move as easily with fine particulate matter dusts on long distances from the emission sources [1]. It is estimated that the main sources of metal emission in Poland are energy-production processes. [12]. The fuel combustion processes introduce from 50 to 90% of metals [13]. The metal deposition from the atmosphere onto the surface of the soil and plants may have a significant influence upon the balance of these components in the soil [16].

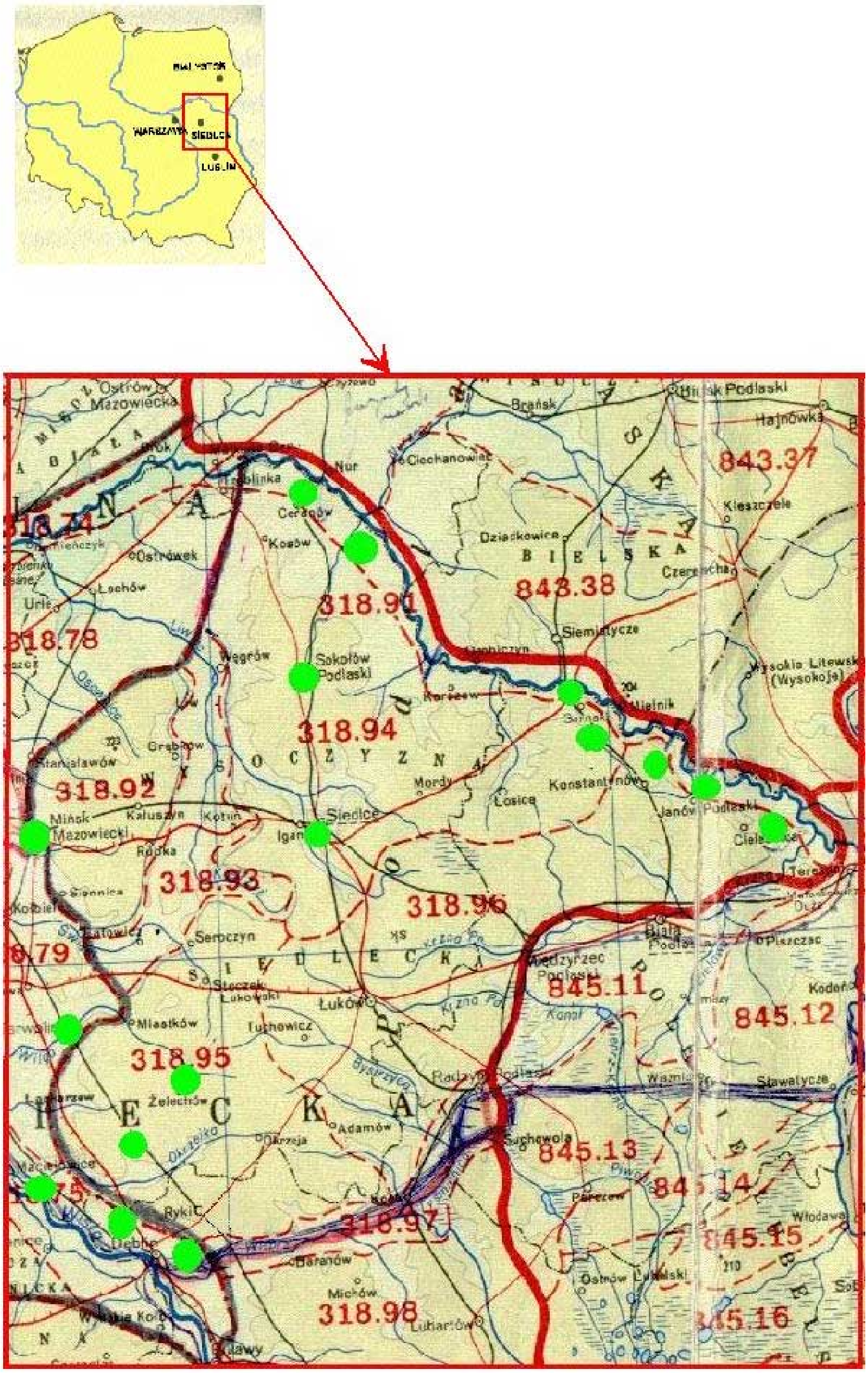
The eastern regions of Poland, including Southern Podlasie Lowland, are one of the country's ecologically clean regions [31]. The main metal sources in this area are first of all the coal combustion processes and pollution generated by communication. The incoming pollution from the South and South-West directions have some contribution to the pollution of the Eastern regions of Poland [14,2].

The elaboration presents investigation directed to a complex evaluation of the level of heavy metal content in falling dusts, soil and dandelion (*Taraxacum officinale* Webb.) in the areas of the South Podlasie Lowland.

MATERIAL AND METHODS

The research was conducted in the years of 1995-1999 in the area of 16 locations of Southern Podlasie Lowland [21], where 33 measurement points were located (Fig.1). The samples were collected from the following locations: Siedlce, Mińsk Mazowiecki, Sokołów Podlaski, Garwolin, Dęblin, Maciejowice, Trojanów, Żelechów, Sobolew, Repki, Jabłonna Lacka, Hołowczyce, Mierzwice, Konstantynów, Janów Podlaski i Bohukały. The atmospheric dusts (dry and wet deposition) were collected into photographic trays the size of 0,1 m^2 once a month or once every quarter for at least one year at the altitude of approx. 2,5 m from the land surface. This way of collecting samples of atmospheric dusts is recommended by, for example, the Central Laboratory of Radiological Protection in order to determine the global beta subsidence and the radioactive nuclides content in the falling dusts [26]. The samples were collected in the dust emission points, the soil and the dandelion's (*Taraxacum officinale* Webb.) leaves and root. The soil samples were collected from the superficial layer up to the depth of approx. 20 cm. In total, 217 dust samples, 124 soil and dandelion samples were analysed in the given area.

Fig.1. The area of investigations and location of the sampling sites



PRINT

The dust samples collected, including rain water, were evaporated to dryness in a porcelain evaporator. Subsequently, the samples were mineralised in a muffle furnace in the temperature of 420°C for 24 hours. The mineralised samples were weighed, and then the samples weighing $\leq$1g were dissolved hot in 2 cm^3 of condensed nitrogen acid (analytically pure) with 0,5 cm^3 of 30% hydrogen peroxide (analytically pure). The solution was percolated into the measuring flasks of 50 cm^3 capacity. The sediment on the filter was washed hot with approx. 10 cm^3 1 mole HNO_3 dm^{-3}. The content of the measuring flasks was supplemented with distilled water up to the marking line.

The soil samples collected were dried with air, the samples were homogenized and subsequently, 5-gramm samples were weighed and mineralised in the muffle furnace in the temperature of 420°C for 24 hours. After the mineralisation, the samples were dissolved similarly as the dusts sediments.

The leaves and roots of the dandelion were washed thoroughly with distilled water and dried in the air. The samples were averaged and the dry mass was collected from 2-gramm samples of the leaves and roots. Subsequently, mineralization in the muffle furnace took place in the temperature of 420°C for 24 hours. The next procedures were the same as for the dusts and soil samples.

In the solutions achieved as a result of mineralization and dissolving of the remaining parts in nitrogen acid, the quantities of the following selected elements: Cd, Pb, Cu, Zn, Mn, Fe and Ni were marked by means of the AAS method. Marking the heavy metals with the AAS method was conducted by means of a Carl Zeiss Jena AAS 30 device, using the acetylene – oxygen flame in the analysis. The content of Cd and Pb in the plant samples was analysed with the use of a graphite tray.

Apart from the metal content, the reaction of the examined soils was determined. In order to specify the pH of soil, 10-gramm dry soil samples were weighed in the air, 25 cm^3 1-mole KCl dm^{-3} was added. Subsequently, the reaction of the suspension was measured with a pH meter after 24 hours.

Given the weight of the dust collected, the amount of days of sampling, the tray's surface (0,1 m^2) and the results of the heavy metal content in the samples analysed, the following values were calculated: daily dust deposition, daily deposition of each metal per unit of surface and metal concentration in the falling dust. Furthermore, mean concentration of chemical elements in the soil was calculated, and the reaction of the soil was determined. Moreover, the concentration of metals in the leaves and root of the dandelion was specified.

On the basis of the results of metal concentration in the dusts, soil and dandelion, the enrichment coefficients were calculated in the following arrangement: dandelion leaves/air, dandelion root/soil and air/soil. When calculating the enrichment coefficients, the following dependence was used [4,17]:

$$EC = \frac{C_1Me / C_{1n}}{C_2Me / C_{2n}}$$

C_1Me – the examined element content in the examined environment
C_2Me – the examined element content in the reference environment
C_{1n} - the reference element content in the examined environment

PRINT

C_{2n} - the reference element content in the reference environment,
when Mn was applied as the reference element.

The results of the mean contents of the elements in the analysed, for particular collection points, samples underwent statistical analysis with the calculation of the (Pearson's) simple correlation coefficients between the metal concentration in the dandelion leaves and root, the metal concentration in the dandelion root and in the soil, the metal concentration in the falling dusts and the dandelion leaves, and the metal concentration in the falling dusts and soil. When calculating the correlation coefficients, the "Statistica" computer programme was applied [35].

RESEARCH RESULTS

The dusts. The mean daily metal deposition in the area under study was as follows: for cadmium and nickel it was at the level of single $\mu g \cdot m^{-2}$, for copper, manganese and lead, it reached the values of several dozen $\mu g \cdot m^{-2}$, the deposition of zinc was slightly above 800 $\mu g \cdot m^{-2}$ on average, and iron above 1000 $\mu g \cdot m^{-2}$. After conversion into the annual deposition, particular metals subsided on average in the following amounts: Cd – 0.8, Pb – 23.7, Cu – 5.8, Zn – 296.5, Mn – 19.8, Fe – 469.5 and Ni –2.15 mg m^{-2}. As for metal concentration in the falling dusts ($\mu g \cdot g^{-1}$), it amounted to: Cd – 42.0, Pb – 561.7, Cu – 82.9, Zn – 3442.6, Mn – 333.4, Fe – 9015.4, Ni – 29.9 (Table 1) in the area of Southern Podlasie Lowland.

Table 1. The deposition and the concentration of heavy metals in falling dust in the chosen area of the South-Podlasie Lowland

Element	The deposition of heavy metals			The concentration of heavy metals in falling dust	
	$\mu g \cdot m^{-2}$ daily $^{-1}$		$mg \cdot m^{-2}$ year $^{-1}$		
	Mean values ±SD	Measuring range	Mean values	Mean values ±SD	Measuring range
Cd	2.2±2.5	0.11-9.3	0.80	42.0±61.5	0.5-253.3
Pb	65.0±63.9	3.4-305.8	23.7	561.7±672.3	31.1-3466.3
Cu	15.9±22.8	0.8-112.3	5.8	82.9±61.1	8.9-226.2
Zn	812.4±1236.1	6.6-4934.1	296.5	3442.6±5207.1	122.7-20716
Mn	54.3±25.8	4.4-93.4	19.8	333.4±156.8	63.9-701
Fe	1286.2±1321.1	135.4-6530.0	469.5	9015.4±4842.8	2282.5-18967.3
Ni	5.9±10.9	0.6-60.0	2.15	29.9±17.0	8.0-65.0

The soil. Among the marked metals, Fe and Mn were in the highest concentration in the soil. The mean concentration of Fe in the examined area was 2529.3 $\mu g \cdot g^{-1}$, and of Mn - 135.4 $\mu g \cdot g^{-1}$. The concentration of Zn and Pb was at the values of tens of $\mu g \cdot g^{-1}$; the values were 57.5

and 23.1 respectively. Cu and Ni were in the single values of μg · g^{-1}; 4.9 and 3.6 respectively. The reaction of the examined soils was in a broad range of pH values, from 4.61 (acid soils) to 7.80 (basic soils) (Table 2).

Table 2. The concentration of heavy metals [μg · g^{-1}] in soil and reaction of soils in the chosen area of the South-Podlasie Lowland

Element	Mean values ± SD	Measuring range
Cd	0.3±0.11	0.06-0.52
Pb	23.1±21.2	2.1-94.3
Cu	4.9±4.0	0.63-18.3
Zn	57.5±70.5	8.3-383.1
Mn	135.4 ±78.3	39.5-314.7
Fe	2529.3±1740.3	567.9-6365.0
Ni	3.6±3.0	0.35-10.9
PH	6.78±0.68	4.61-7.8

Dandelion (*Taraxacum officinale* Webb.). Among the marked elements, Fe and Zn were in the highest concentrations in the dandelion leaves. Their mean concentrations were 236.7 and 64.6 μg · g^{-1} respectively. Similarly as zinc, Mn (28.8) and Cu (10.6) were in the values of tens of μg · g^{-1} in the leaves. Pb (4.55) and Ni (1.56) were at the level of single μg · g^{-1}. Cd was in the lowest concentration. Its mean value was 0.37 μg · g^{-1}. In the dandelion root, the elements were in the decreasing concentration values, similarly as in the leaves, in the sequence Fe>Zn>Mn>Cu>Pb>Ni>Cd. Mean concentrations of particular metals in the dandelion root (μg · g^{-1}) amounted to: Fe – 189.9, Zn – 34.8, Mn – 21.2, Cu –8.35, Pb – 2.63: Ni – 1.04 and Cd – 0.3.

Table 3. The concentration of heavy metals in leaves and root of *Taraxacum officinale* (Webb.) (μg · g-1) in the chosen area of the South-Podlasie Lowland

Element	Leaves of *Taraxacum officinale*		Root of *Taraxacum officinale*	
	Mean values ± SD	Measuring range	Mean values ± SD	Measuring range
Cd	0.37±0.27	0.08-1.3	0.3±0.43	0.03-1.95
Pb	4.55±3.28	0.5-10.72	2.63±2.77	0.06-11.60
Cu	10.6±6.06	2.2-28.3	8.35±4.70	1.5-20,2
Zn	64.6±35.25	18.7-137.7	34.8±27.2	5.0-96.1
Mn	28.8±22.10	5.0-102.2	21.2±19.7	1.0-106.2
Fe	236.7±189.9	47.0-758.3	189.9±181.7	25.8-708.3
Ni	1.56±1.82	0.28-8.90	1.04±0.92	0.14-3.80

PRINT

In order to check the existence of dependencies between the metal concentration:

- in dandelion leaves and root,
- in dandelion root and in soil,
- in falling dusts and in dandelion leaves,
- in falling dusts and in soil,

the correlation coefficients were calculated. Statistically significant dependencies were noticed among:

- the content of the following elements in the dandelion leaves and root: Cd ($r = 0.62^{***}$), Pb ($r = 0.71^{***}$), Cu ($r = 0.57^{***}$), Zn ($r = 0.69^{***}$), Mn ($r = 0.71^{***}$) and Fe ($r = 0.45^{**}$),
- the concentration of Cu in falling dusts and in dandelion leaves (r = 0.30),
- the content of Pb ($r = 0.42^{*}$), Zn ($r = 0,35^{*}$) in dandelion root and in the soil,
- the concentration of Zn in falling dusts, and its content in the soil ($r = 0.35^{*}$) (Table 4).

Table 4. The correlation coefficient between:
A - concentration of heavy metals in leaves and root of *Taraxacum officinale* (Webb.)
B - concentration of heavy metals in root of *Taraxacum officinale* (Webb.) and soil
C - concentration of heavy metals in falling dust and leaves of *Taraxacum officinale* (Webb.)
D - concentration of heavy metals in falling dust and soil

element	A	B	C	D
Cd	0.62^{***}			
Pb	0.71^{***}	0.42*		
Cu	0.57^{***}		0,30 (p<0.1)	
Zn	0.69^{***}	0.35*		0.35*
Mn	0.71^{***}			
Fe	0.45^{**}			

*** p<0.001
**p<0.01
*p<0.05, gdzie p – poziom istotności

The values of enrichment coefficients calculated in the following arrangements: falling dusts/soil, dandelion leaves/dusts, dandelion root /soil are compiled in Table 5. Among the elements under study, in relation to the metal content in the soil, the falling dusts were most enriched with: Cd (EC = 56.9), Zn (EC = 24.3), Cu (EC =17) and Pb (EC = 9.9) and least enriched with Ni (EC = 3.4) and Fe (EC = 1.4). In the arrangement: metal concentration in dandelion leaves / metal concentration in falling dusts, the enrichment coefficients were below 1; only the enrichment coefficient value for Cu equalled 1.5. The enrichment coefficient values for the arrangement of: dandelion root /soil indicate that the dandelion root, in relation to the content in the soil, is enriched mainly with metals: Cu (EC = 10.9), Cd (EC = 6.3) and Zn (EC = 3.9).

PRINT

Table 5. The enrichment coefficient (EC) in relation to:
A - falling dust/soil
B - leaves of *Taraxacum officinale* (Webb.)/falling dust
C - root of *Taraxacum officinale* (Webb.)/soil

element	A	B	C
Cd	56.9	0.1	6.3
Pb	9.9	0.09	0.73
Cu	17.0	1.5	10.9
Zn	24.3	0.22	3.9
Fe	1.4	0.3	0.5
Ni	3.4	0.64	1.9

DISCUSSION

In the area of Southern Podlasie Lowland, the deposition of metals per unit of surface and their concentration in the falling dusts were, as expected, lower than the values recorded in the 1990s in the area of Upper Silesia [6,37], higher, however, than those recorded also in the 1990s in Western Europe [24,25], and also in Lithuania [5] or Saudi Arabia [28].

The main sources of environmental pollution in the area under study are the power engineering processes. In the Eastern areas of Mazowieckie region (the areas of Southern Podlasie Lowland), a higher deposition and concentration of Zn and Pb dusts are recorded in the heating season than in the summer [22]. This is also confirmed by the results available in this elaboration. The highest enrichment coefficients values in the arrangement of: falling dusts/soil are achieved by the metals that are the most volatile ones among the examined elements, i.e. Cd, Pb and Zn and that reach high emission indicators from the processes of power-engineering use of fuels [12]. Therefore, the main sources of heavy metals in the area under study are the power engineering processes connected with fuel combustion. Both the local sources and the incoming contamination contribute to the atmosphere pollution in the researched area. Hryniewicz and Przybylska [14] proved that the Eastern regions of Poland are under the influence of pollution coming from the regions of Western and South-Western Poland.

The usefulness of the enrichment coefficients in the evaluation of the anthropogenic environmental pollution with heavy metals is indicated in the literature [36]. It is assumed that at the enrichment coefficient values (EC) below 2, there is no anthropogenic pollution, the values of EC between 2 and 5 indicate temperate pollution, from 5 to 20 – significant pollution, over 20 – high heavy metal enrichment from anthropogenic sources. In the area under study, the enrichment coefficients reached the highest values for Cd, Zn, Cu and Pb in the arrangement of: metal concentration in falling dusts/ metal concentration in the soil. This confirms the fact that metals get into the environment mainly from the anthropogenic sources.

In the researched area, the exceeding of values standardized by the Polish legislature was not recorded for the mean values in the falling dusts, i.e. the deposition of Pb and Cd (Appendix

PRINT

1998). However, some local exceeding of the norms of lead deposition was recorded in some points and research periods.

The mean metal content in the soil for the majority of analyses corresponded to the natural metal content in the soils. Yet in some sample collection points, a higher level of metal content in the soil was recorded in relation to the natural content ("I" degree of soil pollution with heavy metals) [16].

In the examined soils, higher content of Cd, Pb and Zn was recorded in comparison with the mean contents of these elements in parent rocks adopted as the geo-chemical background [7]. Therefore, the elements that get into the atmosphere in the largest quantities from the coal combustion processes gather in the soils in higher amounts in relation to their content in parent rocks. This is confirmed by a statistically significant dependence ($r=0.35^*$) that occurred between the concentration of zinc in the falling dusts and its concentration in the soil. This indicates that the dust deposition in Southern Podlasie Lowland has a significant impact on the environment pollution with this element.

The level of metal concentration in dandelion leaves and root appeared to be interesting. In accordance with the ranges of dandelion concentrations suggested in the literature and adopted as the background [18,32], the mean metal contents in dandelion leaves and root did not exceed the following values respectively for: Cd – 0.1 and 0.1, Pb - 6.5 and 5.0, Cu –20.0 and 43, Zn –110 and 60, Mn – 170 and 50, Fe –550 and 300, Ni – 6.2 and 6.6 $\mu g \cdot g^{-1}$. However, when analysing the range of the marked metal concentrations in dandelion leaves and root, it is possible to notice that in the area researched, the background concentration values in the leaves were exceeded practically for all the researched metals and in dandelion roots for Cd, Pb, Zn, Mn and Fe. When comparing, for example, the mean values of metal concentration in dandelion leaves with the values recorded in Warsaw [8], several-fold lower values were recorded in Southern Podlasie Lowland than the metal concentrations in the samples of this plant collected near busy streets or parks of Warsaw. According to Czarnowska and Milewska [8], traffic causes the increase of the content of Zn, Fe, Cd and Pb in dandelion leaves. In Southern Podlasie Lowland, the enrichment coefficients in the arrangement of: metal concentration in falling dusts/ metal concentration in dandelion leaves reached relatively low values, usually below 1. Only for copper, the enrichment coefficient in the arrangement in question amounted to 1.5. Also for copper, sufficiently statistically significant correlation ($r=0.30$, $p<0.1$, $n=33$) was noted between the concentration of this element in falling dusts and its concentration in dandelion leaves.

Among the examined heavy metals, copper is found in the largest quantities (approx. 30%) in the falling dusts in the form of soluble compounds, whereas the quantity of iron is only several per cent [23,27]. The forms of copper occurrence in falling dusts may contribute easier to the accumulation of this element in dandelion leaves.

Among the marked elements, statistically relevant correlation between the metal concentration in dandelion root and in the soil was recorded only for Pb ($r=0.42^*$) and Zn ($r=0.35^*$). The enrichment coefficient values calculated in the arrangement of: dandelion root /soil reached values above 1 for Cd, Cu, Zn and Ni. Burczyk et al [4] indicated higher enrichment coefficient values in the plant/soil arrangement in comparison with the plant/air arrangement. High correlation coefficient values in the arrangement of: dandelion leaves/root and enrichment coefficients with metals in the arrangement of: dandelion root /soil indicate that the main way of metal absorption by the dandelion is the root system. This way of metal absorption by plants was pointed by, among others, Hegemayer et al [11] and Gambuś [9]. The research results indicate that dandelion root is a rich source of micro-elements: Cu and Zn. In the conditions of distinctly higher content of Cu, Zn and Cd in the soil, the dandelion root may contribute to the de-toxication of the soil from these elements. This latter statement requires, however, confirmation on a research material collected from the areas of higher heavy metal contamination than Southern Podlasie Lowland.

The research results indicate that in the agricultural lands not contaminated excessively with heavy metals, the dandelion root may be a good indicator of the metal level, predominantly Pb and Zn in the soil. The usefulness of dandelion leaves is less significant in the evaluation of the metal deposition value and the metal concentrations in dusts. These elements get into the environment in the largest quantities with the power engineering processes, and reach higher emission levels during the heating season than in the period of plant vegetation.

CONCLUSIONS

1. In selected areas of Southern Podlasie Lowland, the mean deposition of Cd and Pb from 1995 to 1999 did not exceed the values standardised in the Polish legislature, and the mean metal concentration in the soils corresponded to their natural content. The mean metal concentration in dandelion leaves and root was in the range of values suggested as the background in the literature.
2. The main sources of Cd, Pb, and Zn in the researched areas are the coal combustion processes, which is indicated by high values of enrichment coefficients in dusts in the arrangement of: metal concentration in dusts/metal concentration in soil. The mean concentration of these elements in the soils exceeds the values of the geo-chemical background.
3. In agricultural lands not loaded excessively with heavy metals, the metal level in the root is of higher significance than in the leaves of the plant when using dandelion for the bio-indicatory purposes. This is indicated by high enrichment coefficient values in the arrangement of: dandelion root /soil for the following elements: Cd, Cu, Zn and Ni and statistically significant correlation between the content of Pb and Zn in the soil and dandelion root.

REFERENCES

1. Bartnicki J., Hrehoruk J., Olendrzycki K. 1994, Evalution of Poland's contribution to atmospheric transport of heavy metals over Europe. Arch.Ochr.Środowiska, 3-4: 39-66. [in Polish]
2. Berge E., Bartnicki J., Olendrzyncki K., Tsyro S. G., 1999. Long-term trends in emission and transboundary transport of acidifying air pollution in Europe. Journal of Environmental Management. Vol. 57, No. 1: 31-50.
3. Borowska K. 1996. Selenium content in different parts of *Medicago Sativa* and *Taraxacum officinale* from selected alfalfa plantations located on three types of soil. Roczniki Gleboznawcze; t. XLVII, Nr 3/4: 239-245. [in Polish].
4. Burczyk J., Wiechuła D., Mirosławski J., Dorda E., Paukszto A., Rochel R., Kwapuliński J. 1994. Plants contamination in industrial emission range based on Cieszyn. Ochrona Powietrza i Problemy Odpadów, Nr 3 (161): 124-127.[in Polish].

PRINT

5. Čeburnis D. 1999. Atmospheric trace metal deposition in Lithuania; methods and estimation. In: Heavy metals in the Environment, An: Integrated Approach. Ed. D.A. Lovejoy, Institute of Geology, Lithuania, 5-15.
6. Ciepał R. 1999. Cumulation of heavy metals and sulphur in plants of selected species as well as in the soil as an indicator of the degree of pollution in the territories under environment protection of Silesia and Malopolska provinces. Wyd. Uniwersytetu Śląskiego, Katowice. [in Polish].
7. Czarnowska K. 1996. Total content of heavy metals in parent rocks as geo-chemical reference background of soils. Roczniki Gleboznawcze T. XLVII Supl. Warszawa: 43-50. [in Polish].
8. Czarnowska K., Milewska A. 2000. The Content of Heavy Metal in an Indicator Plant (*Taraxacum officinale*) in Warsaw. Polish Journal of Environmental Studies, Vol. 9, No. 2: 125-128.
9. Gambuś F. 1997. Heavy metals absorption by various cultivated plant species. Part II. Heavy metals accumulation by plants. Acta Agraria et Silvestria, Series Agraria. Vol. XXXV: 21-29. [in Polish].
10. Godzik B. 1992. *Mochringia triervia* (L.) Clairv. – a bioindicator of heavy metal pollution of the environment. Acta Societatis Botanicorum Poloniae, Vol. 61(3-4): 409-417.
11. Hegemayer J., Kahle H., Breckle S. W., Waisel Y. 1986. Cadmium in Fagus sylvatica L. trees and seedlings: leaching, uptake and interconnection with transpiration. Water, Air and Soil Pollut., 29, 4: 347-359.
12. Hławiczka S. 1994. Metals emission to the atmosphere from the power-engineering use of fuels in Poland. Part I. Hard coal combustion. Ochrona Powietrza i Problemy Odpadów, 6 (164): 143-145. [in Polish].
13. Hławiczka S. 1997. Heavy metals in the air – a problem not only of Poland. Aura 1: 10-12.Hryniewicz R., Przybylska G. 1993. Actual and predicted air pollution and deposition rates of pollutants in north eastren Poland. Ekol. Pol., 41(1/2): 75-104. [in Polish].
14. Hryniewicz R., Przybylska G. 1993. Actual and predicted air pollution and deposition rates of pollutants in north eastren Poland. Ekol. Pol., 41(1/2): 75-104.
15. Jasiewicz Cz., Antonkiewicz J. 1999. The influence of soil contamination with heavy metals on the chemical composition of *Sida Hermaphrodita* rusby. Chemia i Inżynieria Ekologiczna, t.6, Nr 5-6: 419-427. [in Polish].
16. Kabata-Pendias, Dudka S., Tarłowski P. 1995. Atmospheric fallout of trace elements from the atmosphere to the soil surface. Rocz. Gleboznawcze, T. XXXVI, Nr 1: 137-140. [in Polish].
17. Kabata-Pendias A, Pendias H. 1993. Bio-geo-chemistry of trace elements]. Wyd. Naukowe PWN. [in Polish].
18. Kabata-Pendias A., Dudka S. 1991: Dandelion (*Taraxacum officinale*) as a convenient indicator of metal pollution. J.Geochem. Health, 13: 108-113.
19. Kabata-Pendias A., Piotrowska M., Motowicka-Terelak T., Maliszewska-Kordybach B., Filipiak K, Krakowiak A., Pietruch C. 1994. Bases for the assessment of the soils chemical contamination. Heavy metals, sulphur, polycyclic aromatic hydrocarbons. Biblioteka Monitoringu Środowiska, Warszawa. [in Polish].
20. Kisku G.C., Barman S.C., Bhargava S. K. 2000. Contamination of soil and plants with potentially toxic elements irrigated with mixed industrial effluent and its impact on the environment. Water Air and Soil Pollution, 120: 121-137.
21. Kondracki J. Physical geographic of Poland. PWN, Warszawa. [in Polish].
22. Królak E. 2000. Heavy metals in the falling dust in the eastern Mazowieckie province. Polish Journal of Environmental Studies, Vol. 9, No. 6: 517-522.
23. Królak E., Jurkiewcz-Karnkowska E. The share of atmospheric precipitation in heavy metal contamination of two lowland dam reservoirs (Zegrzyński and Siedlecki Reservoirs, Mazowieckie Province, Poland). Chemia i Inżynieria Ekologiczna, w druku. [in Polish].
24. Lisiewicz M., Golimowski J., Krauß P., Wallenhorst T. 1998. Load of Pb, Cd, Hg, Be and Cu with Sedimenting Dusts in the City of Karlsruhe in Winter 1992/93 – Autumn 1993 Period. A. Spatial and Temporal Variation Study. Chem. Anal. (Warsaw), 43, 881-886.
25. Maneux E., Grousset F.E., Baut-Mnard P., Lavaux G., Rimmelin P., Lapaquellerie Y. 1999. Temporal patterns of the wet deposition of Zn, Cu, Ni, Cd and Pb: The Arcachon Lagoon (France). Water' Air and Soil Pollution 114: 95-120.
26. Method of global activity measurement of ß-absolute fallout. 1977. Centralny Ośrodek Pomiarów Skażeń Promieniotwórczych. Warszawa. [in Polish].
27. Mirosławski J., Kwapuliński J., Brodziak B., Podleska J., Matera L., Wróbel H., Bogunia M.1999. Heavy metals speciation in dusts in the close-to-ground air layer in the recreation area (on the example of Brenna commune). Ochrona Powietrza i Problemy Odpadów, Vol. 33, nr 5:183-188. [in Polish].
28. Modaihsh A.S. 1997. Characteristics and composition of the falling dust sediments on Riyadh city, Saudi Arabia. Journal of Arid Environments. Vol. 33, No. 2: 211-223.

PRINT

29. Namieśnik J., Wardencki W. 2000. Application of vegetation in environmental biomonitoring. Chemia i Inżynieria Ekologiczna, T. 7, Nr 3: 189-208. [in Polish].
30. Porębska G., Ostrowska A. 1999. Heavy Metal Accumulation in Wild Plants: Implications for Phytomediation. Polish Journal of Environmental Studies, Vol. 8, No 6: 433-442.
31. Report on the environmental conditions of Siedlce Province in the years of 1995-1996]. 1997. Biblioteka Monitoringu Środowiska. Siedlce. [in Polish].
32. Rule J.H. 1994. Use of small plants as phytomonitors with empasis on the comimon dandelion, Taraxacum officinale. In: D.C. Adriano, Z. Chen, and S. Yand (eds.). Biogeochemistry of trace Elements, Environmental Geochemistry and Health, Special Issue, Vol. 16: 627-654.
33. Rule J.H. 1997. Site investigations for inorganic element contamination utilizing selective soil extractions and phytom onitors. W: Obieg pierwiastków w przyrodzie, Materiały z II Międzynarodowej Konferencji, Warszawa 27-29 X 1997. Instytut Ochrony Środowiska, 213-219
34. Samecka-Cymerman A., Kempers A., J. 1999. Bioindication of heavy metals in the town Wrocław (Poland) with evergreen plants. Atmospheric Environment 33: 419-430.
35. Stanisz A. 1998. Popular course in statistics. Wyd. Stat. Soft, Polska, sp. z o.o. [in Polish].
36. Sutherland R. A. 2000. Depth Variation in Copper, Lead, and Zinc Concentrations and Mass Enrichment Ratios in Soils of an Urban Watershed. J. Environ. Qual. 29: 1414-1422.
37. Wiechuła D., Mirosławski J., Kwapuliński J., Sowada B., Manderla J. 1996. Biomarkers in environmental toxicology. W: Biologiczne monitorowanie skażenia środowiska. Red. A.K. Siwicki, Wyd. IRS, 13-35. [in Polish].
38. Appendix to the Instructions of the Minister of Environmental Protection, Natural Resources and Forestry from 28.04.1998. Dz.U.nr 55, poz. 355. [in Polish].

Submited:

Elżbieta Królak
Department of Ecology and Environmental Protection
University of Podlasie
12 Prusa, 08-110 Siedlce, Poland
tel. (0 25) 643 12 17
fax. (0 25) 643 13 38
e-mail: ekologia@ap.siedlce.pl
