

REGARDING TRANSFER FACTOR OF SOIL POLLUTION WITH HEAVY METALS IN SOIL-PLANT SYSTEM

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Abstract

Heavy metals such as lead (Pb), cadmium (Cd), nickel (Ni), zinc (Zn), copper (Cu) present in large amounts in soil surface horizons are chemically stable compounds. They are complexed with various organic or inorganic ligands, which amplifies their toxicity. They, as we know, produce negative effects in different plant organs, and by transfer in the food chain produce different pathologies in animals and humans. The aim of the present work was to determine the transfer factor of lead (Pb) and cadmium (Cd) from soil to crop plants based on the concentrations determined for these elements. The transfer factor (TF) values were calculated for lead (Pb) and cadmium (Cd). Thus, the transfer factor for Cd was much higher than that for Pb, but the values do not exceed the reference value, namely 1.

Key words: environmental impact, food chain, heavy metals, soil pollution, transfer factor.

INTRODUCTION

Because of potential effects on food and environmental safety, research on the transfer of heavy metals from soil to plants has become increasingly important. Lead and cadmium are two examples of heavy metals that can accumulate in soils because of natural and anthropogenic processes, including mining, prolonged industrial emissions and excessive use of chemical fertilizers. One in the soil, these metals can enter the food chain via plant uptake; depending on physiological and ecological conditions, different species may show different levels of tolerance and accumulation capacity (Lăcătușu et al., 1998; Cordoș, 2003; Lăcătușu et al., 2007; Coman & Dăscălescu, 2008; Yadav, 2010; Roba et al., 2015; Hreniuc et al., 2020; Taro and Coman, 2021; Rusin et al., 2021; Filip & Coman, 2023; Filip & Coman, 2024a).

The species of the genus *Prunus*, namely the plum (*Prunus domestica* L.) is cultivated because its fruits are nutritionally rich, appreciated for their flavor, yields are high at low cost and there is an increased possibility of exploiting the fruit (from fresh consumption to jam, marmalade, distillate products by specific processes, etc.). Plums are also more resistant to

shattering than the fruits of other species of fruit trees. The relationship between heavy metals and prunes can be described by the action of antioxidants. It is known that heavy metals when they enter the body can generate free radicals and reactive oxygen or nitrogen species that can damage DNA, proteins and lipids. The antioxidants in plums act as protective shields, neutralizing free radicals and preventing cell damage. Although, prunes also stand out as an ally against oxidative stress, and nature seems to offer ways to mitigate the negative effects of heavy metals (Mitre, 2001; Oprea & Ropan, 2010; Boškovic-Rakocevic et al., 2014; Stoica & Giurgiulescu, 2016; Giurgiulescu et al., 2017; Mitre, 2021; Rusu et al., 2023; Rusu et al., 2024).

Like other fruit tree species, the plum, through its root system, also absorbs heavy metals from the soil, which can influence fruit quality and pose potential health risks to consumers. Therefore, understanding the dynamics of heavy metals transfer from the soil to the different organs of these plants and their accumulation of is essential for our food safety.

Several studies in the literature have examined bioaccumulation trends in different crops, but there is still a relative lack of data on heavy

metal transfer rates to crop plants of the genus *Prunus* (Lațo et al., 2012; Mirecki et al., 2015; Mao et al., 2019; Prabasiwi et al., 2020; Mostafa et al., 2021; Lere et al., 2021; Oladele et al., 2023).

The present paper aims to quantify the transfer capacity of soil heavy metal pollutants in *Prunus* fruits from different private farms present in the Baia Mare Depression, more precisely in the area of glacis and contact piedmont. Detailed analyses were performed for 2 heavy metals, Pb and Cd.

MATERIALS AND METHODS

Characteristics of the studied area

The area of interest (polluted area) is a large one of approximately 588.8 km², in the Baia Mare Depression comparing with a cleaner area in the Maramureș Depression, namely the Sighetu Marmăției area, which is of 111 km². From these perimeters, soil samples were taken from different sampling depths according to Order No. 184/1997 and plum samples according to Order No. 184/2001.

The Baia Mare Depression (Figure 1) represents the contact zone between the Someșan Plateau and the Eastern Carpathians, located on the southern flank of the Gutâi and Țibleș Neogene. From the altimetric point of view, the base level of the depression varies between 150 and 350 m, while from the morphologic point of view it has a bowl shape. The relief is varied, and this paper focuses on the Seini - Baia Mare - Baia Sprie piedmont glacis, towards the southern flank of the Igriș-Gutâi Mountains (Badea et al., 1992; Coman, 2006; Coman, 2010a; Ștefan et al., 2012; Marian et al., 2016).

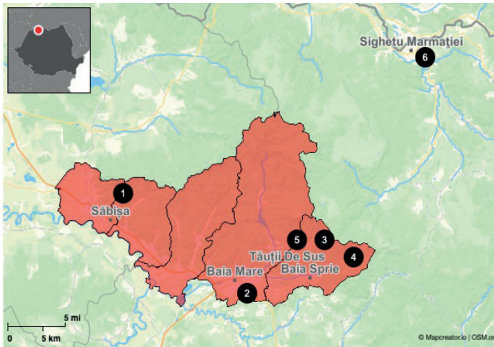


Figure 1. Sampling points in the Baia Mare Depression

As can be seen in Table 1, the minimum altitude is 252.9 m, and the maximum altitude is 356.4 m. All the farms are privately owned, well-kept properties.

Table 1. Sampling points

Point	Study area	Latitude	Longitude	Altitude (m)
1	Săbișa	47°44.1370'N	23°19.7050'E	270.9
2	Baia Mare	47°38.6340'N	23°35.3340'E	252.9
3	Baia Sprie I	47°39.8030'N	23°40.6890'E	343.9
4	Baia Sprie II	47°40.0090'N	23°40.5120'E	348.9
5	Tăuții de Sus	47°39.7710'N	23°37.1040'E	272.4
6	Sighetu Marmăției	47°54.6710'N	23°56.8360'E	356.4

Working method

Soil sampling. Existing methodological regulations and standards, i.e. Order No 184/1997, are followed.

Soil samples were taken from the Baia Mare Depression (glacis and contact piedmont area) and Sighetu Marmăției in the Maramureș Depression as a control sample. The soil profile was opened, and soil samples were taken from different depths, respectively 5, 30, 50 and 100 cm. After soil sampling, physic-chemical analyses were performed in an accredited laboratory, namely INCDO ICIA Cluj-Napoca according to ISO standards: SR ISO 11464:1994; SR ISO 11047:1999-PIS-03; SR EN ISO 1185:2009.

The values are compared with the legislation in force at national level, i.e. Order 756/1997, at European level, European Council Directive 86/278/EEC 1986, and at international level, (US EPA, 2002 after He et al., 2015b).

Fruit samples. Fruit sampling was carried out in August 2023 and August 2024, from the same locations where soil samples were taken. After sampling, the samples were transported following the transport rules and analyzed at the accredited laboratory INCDO ICIA Cluj-Napoca according to SR EN ISO 17294-2:2017.

The values are compared with the legislation in force at national level, namely Order No. 975/1998, at European level, namely Commission Regulation (EU) 1881/2006, Commission Regulation (EU) 629/2008, (EU) 2021/1317 completed by Commission Regulation (EU) 2023/915, and at international level, namely (Codex Alimentarius, 1995 and World Health Organization, 1996).

The transfer factor. In this paper, the transfer factor (TF) or in other papers titled as bioaccumulation index (BAF), biological accumulation factor (BCF) or bioconcentration factor (BCF_T) has been calculated according to the literature used at national and international level (Olănescu, 2007; Ivasiuc & Rusu, 2011; Big et al., 2012; Jolly et al., 2013; Nițu et al., 2019; Jakubus et al., 2019; Aladensami et al., 2019; Pehoiu et al., 2020; Noman et al., 2022; Tong et al., 2022; Pruteanu et al., 2022).

$$TF = \frac{Mp}{Ms},$$

where: TF - is the transfer factor (mg/kg);
Mp - represents the metal content in the plant (mg/kg);
Ms - represents the metal content in soil (mg/kg).

Regarding the TF values, on the one hand, if the TF value is >1 it means that the plant has accumulated elements, on the other hand, if the TF value is <1 it means that the plant resists to assimilate elements. Values close to 1 indicate that the plant is not affected by element. The calculation of the values assumes that there is a linear relationship between the concentration of an element in the plant and in the soil (Mihali et al., 2013; Emurotu & Onianwa, 2017; Thien et al., 2021; Olusegun et al., 2023).

RESULTS AND DISCUSSIONS

Soil sampling

The Pb content in total and mobile form at different sampling depths from representative points in the Baia Mare Depression (Săbișa, Baia Mare, Baia Sprie I, Baia Sprie II and Tăuții de Sus) and one point from Maramureș Depression (Sighetu Marmăției) are represented in Table 2.

Sampling points – Pb

In *Săbișa*, the Pb content in total form at all depths is below the maximum permissible limits at international, European and national level. Thus, the soil at this point does not involve the intervention threshold. A small approach to the limit is at 30 cm. The Pb content in mobile form is below 0.10 mg/kg, but no comparison can be made due to lack of clear legislation.

Table 2. Pb content in soil

No. crt.	Sampling point	Depth (cm)	Pb content (mg/kg)	
			Total	Mobile
1.	Săbișa	5	35.0	0.10
		30	42.7	<0.02
		50	22.9	<0.02
		100	21.0	0.09
2.	Baia Mare	5	27.0	<0.02
		30	385.0	<0.02
		50	238.0	<0.02
		100	480.0	<0.02
3.	Baia Sprie I	5	211.0	0.68
		30	88.3	0.34
		50	35.0	0.28
		100	32.8	<0.10
4.	Baia Sprie II	5	261.0	0.60
		30	41.7	<0.10
		50	33.3	<0.10
		100	29.1	<0.10
5.	Tăuții de Sus	5	890.0	0.087
		30	141.0	1.20
		50	35.3	0.16
		100	37.7	0.17
6.	Sighetu Marmăției	5	40.7	<0.02
		30	28.8	<0.02
		50	31.6	<0.02
		100	27.7	<0.02
7.	MAL RO ^a	-	50	-
8.	MAL EU ^b	-	50-300	-
9.	MAL INT ^c	-	200	-

MAL - maximum allowed limit; RO – Romania; EU - Europe; INT – International; a - Order No. 756/1997; b - Council Directive 86/278/CEE 1986; c - US EPA, 2002 after He et al., 2015b.

In *Baia Mare*, the Pb content in total form at a depth of 5 cm is below the maximum permissible limits of the legislation in force, while at 30 cm the value is 7.7 times higher than the reference value. At 50 cm we observe a decrease to 4.8 times the reference value, while at 100 cm we have the highest value recorded, almost 10 times the legislation. Thus, we can state that the pollutant has migrated into the soil and now the limits are exceeded at depths between 30 and 100 cm. The content of Pb in mobile form shows the same value of less than 0.02 mg/kg, but it is not possible to make a comparison due to the lack of clear legislation. In *Baia Sprie I*, the Pb content in total form, at 5 cm we have an exceedance of about 4.3 times

the maximum permissible limits, at 30 cm we have a decrease to 1.8-fold above the maximum permissible limit. As for the depth of 50 cm and 100 cm the limits are not exceeded. The Pb content in mobile form is between 0.1-0.68 mg/kg, but it is not possible to make a comparison due to the lack of clear legislation. In *Baia Sprie II*, content of Pb in total form, at 5 cm depth we have an exceedance of about 5.3 times the maximum permissible limit, and at 30 cm, 50 cm and 100 cm the values are below the maximum permissible limits. The content of Pb in the mobile form is between 0.1-0.6 mg/kg, but it is not possible to make a comparison due to the lack of clear legislation.

In *Tăuții de Sus*, the Pb content in total form, at a depth of 5 cm, has the highest value recorded, over 17.8 times higher than the maximum permissible limits, while at 30 cm are recorded exceedances of about 2.8 times the legislation. The content of Pb in mobile form presents values from 0.087-1.20 mg/kg but it is not possible to make a comparison due to the lack of clear legislation.

In *Sighetu Marmăției* (the control), the total Pb content is below the maximum permissible limits at all the depths where sampling was carried out. The maximum value was recorded at 5 cm, 40.7 mg/kg, while the national legislation stipulates 50 mg/kg. The mobile Pb content is below 0.2 mg/kg, but no comparison can be made due to lack of clear legislation.

Sampling point – Cd

Cd content in total and mobile form at different sampling depths from representative points in the Baia Mare Depression (Săbișa, Baia Mare, Baia Sprie I, Baia Sprie II and Tăuții de Sus) and one point from Maramureș Depression (Sighetu Marmăției) are represented in Table 3.

In *Săbișa*, the Cd content in total form at all depths are below the maximum permitted limits at international, European and national level. The Cd content in mobile form is below 0.2 mg/kg, but no comparison can be made due to lack of clear legislation.

In *Baia Mare*, the content of Cd in total form at a depth of 5 cm is below the maximum permissible limits, while at 30 cm there is an exceedance of about 1.2 times the current legislation. At 50 cm the Cd concentration drops sharply to 0.83 mg/kg, indicating a significant reduction in Cd accumulation. At 100 cm it

shows an exceedance of about 1.4 times the current legislation. The Cd content in the mobile form is below 0.3 mg/kg, but no comparison can be made due to the lack of clear legislation.

Table 3. Cd content in soil

No. crt.	Sampling point	Depth (cm)	Cd content (mg/kg)	
			Total	Mobile
1.	Săbișa	5	<0.33	<0.02
		30	<0.33	<0.02
		50	<0.33	<0.02
		100	<0.33	<0.02
2.	Baia Mare	5	1.73	<0.02
		30	3.47	0.03
		50	0.83	<0.02
		100	4.0	<0.02
3.	Baia Sprie I	5	2.50	<0.05
		30	1.60	<0.05
		50	1.20	<0.05
		100	1.17	<0.05
4.	Baia Sprie II	5	2.57	<0.05
		30	1.27	<0.05
		50	1.40	<0.05
		100	1.23	<0.05
5.	Tăuții de Sus	5	8.80	<0.05
		30	1.67	<0.05
		50	1.43	<0.05
		100	1.33	<0.05
6.	Sighetu Marmăției	5	<0.33	<0.02
		30	<0.33	<0.02
		50	<0.33	<0.02
		100	<0.33	<0.02
7.	MAL RO ^a	-	3	-
8.	MAL EU ^b	-	1-3	-
9.	MAL INT ^c	-	0.48	-

MAL - maximum allowed limit; RO – Romania; EU – Europe; INT – International; a - Order No. 756/1997; b - Council Directive 86/278/CEE 1986; c- US EPA, 2002 after He et al., 2015b.

In *Baia Sprie II*, the total Cd content is below the national and European maximum permissible limits at all sampling depths but exceeds the international values. The Cd content in mobile form shows values below 0.05 mg/kg but it is not possible to make a comparison due to lack of clear legislation.

In *Tăuții de Sus*, the Cd content in total form at the level of the surface horizon, 5 cm, we have a 3-fold exceedance of the maximum permissible limits, while at 30 cm, 50 cm and 100 cm the national and European limits are not exceeded, only the international ones. The Cd content in mobile form shows values of less than 0.05 mg/kg, but it is not possible to make a comparison due to the lack of clear legislation.

In *Sighetu Marmatiei* (the control), the Cd content in total form is below the maximum permissible limits at all sampling depths. We currently have a common value of <0.33 mg/kg. The Cd content in mobile form shows the same value of 0.02 mg/kg, but no comparison can be made due to lack of clear legislation.

Fruit samples

The results on the total form of Pb in fruits, for the year 2023 and the year 2024, are presented in Table 4.

Table 4. Pb content in fruits

No. crt	Sampling point	Pb content in 2023 (mg/kg)	Pb content in 2024 (mg/kg)
1.	Săbișa	<0.04	<0.15
2.	Baia Mare	<0.04	<0.15
3.	Baia Sprie I	<0.04	<0.15
4.	Baia Sprie II	<0.04	<0.15
5.	Tăuții de Sus	<0.04	<0.15
6.	Sighetu Marmatiei	<0.04	<0.15
7.	MAL RO ^a	0.50	
8.	MAL EU ^b	0.10	
9.	MAL INT ^c	0.10-3	

MAL - maximum allowed limit; RO – Romania; EU – Europe; INT –International; a - Order no. 975/1998; b - Commission Regulation (EU) 2023/915; c - C. A., 1995, WHO, 1996.

In this study, for the year 2023, that the Pb concentration was of 0.04 mg/kg, well below the maximum permissible limits (0.1 mg/kg) according to European and international standards and 0.5 mg/kg according to national legislation.

For the year 2024, a significant increase in the Pb content can be observed, reaching 0.15 mg/kg. This value does not exceed the national maximum permissible limit, but in terms of international and European standards it is exceeded by 0.05 mg/kg.

The increase in Pb content in fruits is due to increased periods of drought in 2024 (315.69 mm), so less precipitation than in 2023 respectively, according to National Meteorological Agency (ANM, 2025).

The results on the total form of Cd in fruits for the year 2023 and the year 2024 are presented in Table 5.

This research found, for the year 2023, the Cd concentration was constant at 0.04 mg/kg, which is below the maximum permissible limit of 0.05 mg/kg imposed by national and European

legislation. The values are compliant and do not raise food safety concerns.

Table 5. Cd content in fruits

No. crt	Sampling point	Cd content in 2023 (mg/kg)	Cd content in 2024 (mg/kg)
1.	Săbișa	<0.04	<0.08
2.	Baia Mare	<0.04	<0.08
3.	Baia Sprie I	<0.04	<0.08
4.	Baia Sprie II	<0.04	<0.08
5.	Tăuții de Sus	<0.04	<0.08
6.	Sighetu Marmatiei	<0.04	<0.08
7.	MAL RO ^a	0.05	
8.	MAL EU ^b	0.05	
9.	MAL INT ^c	1-1.3	

MAL - maximum allowed limit; RO - Romania; EU - Europe; INT - International; a - Order no. 975/1998; b - Commission Regulation (EU) 2023/915; c - C. A., 1995, WHO, 1996.

For the year 2024, data indicate an increase of Cd to 0.08 mg/kg at all sampling points. These values exceed the national and European legislation (by 0.03 mg/kg), but in terms of international legislation, the fruit is safe for consumption.

The increase in Cd content in fruit is also due to increased periods of drought in 2024 (i.e. 315.69 mm) less precipitation than in 2023 according to ANM, 2025.

The transfer factor

The transfer factor for Pb and Cd was calculated with the literature formula for the total and mobile forms as specified in the methodology above. The Pb transfer factor, from soil to fruit, for the years 2023 and 2024, in total and mobile form, is shown in Table 6.

In *Săbișa*, the total transfer factor exhibited an increase in 2024 compared to 2023, ranging from a 3.74-fold increase at 100 cm to a 3.89-fold increase at 30 cm depth. A similar trend was observed in the mobile form, with a 3.75-fold increase at 5 cm, 30 cm, and 50 cm, and a 3.77-fold increase at 100 cm, indicating a relatively uniform rise across sampling depths. Exceedances of the transfer factor were recorded at 30 cm and 50 cm, while the mobile transfer factor exceeded threshold values at all depths in 2024.

In *Baia Mare*, a region historically affected by significant industrial pollution, the data from 2024 indicate substantial increases in

contaminant levels, reaching up to 6 times higher than those recorded in 2023.

Table 6. Transfer Factor -Pb

No. crt.	Sampling point	Depth (cm)	TF 2023	TF mobile 2023	TF 2024	TF mobile 2024
1.	Săbișa	5	0.0011	0.40	0.0042	1.50
		30	0.0009	2.00	0.0035	7.50
		50	0.0017	2.00	0.0065	7.50
		100	0.0019	0.44	0.0071	1.66
2.	Baia Mare	5	0.0014	2.00	0.0055	7.50
		30	0.0001	2.00	0.0003	7.50
		50	0.0001	2.00	0.0006	7.50
		100	0.0000	2.00	0.0003	7.50
3.	Baia Sprie I	5	0.0001	0.05	0.0007	0.22
		30	0.0004	0.11	0.0016	0.44
		50	0.0011	0.14	0.0042	0.53
		100	0.0012	0.40	0.0045	1.50
4.	Baia Sprie II	5	0.0001	0.06	0.0057	1.50
		30	0.0009	0.40	0.0035	1.50
		50	0.0012	0.40	0.0045	1.50
		100	0.0137	0.40	0.0051	1.50
5.	Tăuții de Sus	5	0.0000	15.00	0.0001	4.00
		30	0.0002	0.03	0.0010	0.12
		50	0.0011	0.25	0.0042	0.93
		100	0.0010	0.23	0.0039	0.88
6.	Sighetu Marmăției	5	0.0009	2.00	0.0036	7.50
		30	0.0013	2.00	0.0052	7.50
		50	0.0012	2.00	0.0047	7.50
		100	0.0014	2.00	0.0054	7.50

Furthermore, the transfer factor in its mobile form exceeded acceptable thresholds in both years of the study. In 2024, a consistent 3.75-fold increase was observed across the entire soil profile when compared to the previous year, suggesting a uniform upward trend in the mobility and bioavailability of contaminants throughout the sampled depths.

In *Baia Sprie I*, transfer factor values in 2024 showed a substantial increase compared to the previous year, ranging from a 3.75-fold rise at 100 cm to a sevenfold increase at 5 cm depth. This gradient highlights a significant accumulation of contaminants in the upper soil layers. The mobile form of the transfer factor also demonstrated elevated values, increasing between 3.75 and 4.4 times at 5 cm, indicating enhanced contaminant mobility. Notably, exceedances of the mobile transfer factor were recorded only at the 100 cm depth in 2024.

In *Baia Sprie II*, at the surface horizon 5 cm, there is a 57-fold increase in 2024 compared to the previous year. On the one hand, at 30 cm and

50 cm we have a smaller increase of about 4 times in 2024. On the other hand, the transfer factor at the depth layer level at 100 cm has 0.37 times smaller decrease compared to the previous year. Regarding the mobile form, significant differences are found at 5 cm, a 25-fold increase, while at the rest of the depths we have a 3.75-fold increase compared to the previous year. In all samples analyzed from this point, the transfer factor in the mobile form in 2024 exceeds the reference value.

In *Tăuții de Sus*, the transfer factor values in 2024 exhibited a marked increase compared to the previous year, ranging from a 3.82-fold rise at 50 cm depth to a 5-fold increase at 30 cm. These results indicate a significant accumulation of contaminants, particularly in the upper soil layers. In contrast, the mobile form of the transfer factor showed a notable decrease at 5 cm, with values in 2024 being 3.75 times lower than those recorded in 2023. Overall, the increases in transfer factor were more pronounced in the surface horizons compared to deeper layers. Exceedances of the transfer factor for the mobile form were recorded exclusively at the 5 cm depth in both years of the study.

In *Sighetu Marmăției* (the control), transfer factor values in 2024 increased approximately 4-fold compared to those recorded in 2023. Similarly, the mobile form of the transfer factor exhibited a consistent 3.75-fold increase across all sampling depths, indicating a uniform trend in contaminant mobility. Exceedances of the mobile transfer factor were observed in all analyzed samples during both years of the study. The transfer factor from soil to fruit for Cd for the years 2023 and 2024 in total and mobile form is shown in Table 7.

In *Săbișa* the transfer factor in both the form as well as the mobile form increased 2 times in 2024 compared to 2023. Exceeded values are recorded for mobile form in both study years.

In *Baia Mare*, an intensely polluted areal, the transfer factor in total form, at all sampling depths a 2-fold increase compared to the previous year, while the mobile form, records a uniform 3.75-fold increase. Overruns are recorded in both years of the study for the mobile form transfer factor.

In *Baia Sprie I*, there is a 2-fold increase compared to the previous year for both total and

mobile form. Overruns are only recorded for the mobile form for the year 2024.

Tabel 7. Transfer Factor -Cd

No. crt.	Sampling point	Depth (cm)	TF 2023	TF mobile 2023	TF 2024	TF mobile 2024
1.	Săbișa	5	0.1212	2.00	0.2424	4.00
		30	0.1212	2.00	0.2424	4.00
		50	0.1212	2.00	0.2424	4.00
		100	0.1212	2.00	0.2424	4.00
2.	Baia Mare	5	0.0231	2.00	0.0462	7.50
		30	0.0115	2.00	0.0230	7.50
		50	0.0481	2.00	0.0963	7.50
		100	0.0100	2.00	0.0200	7.50
3.	Baia Sprie I	5	0.0160	0.80	0.0320	1.60
		30	0.0250	0.80	0.0500	1.60
		50	0.0333	0.80	0.0666	1.60
		100	0.0341	0.80	0.0683	1.60
4.	Baia Sprie II	5	0.0155	0.80	0.0090	1.60
		30	0.0314	0.80	0.0479	1.60
		50	0.0285	0.80	0.0559	1.60
		100	0.0341	0.80	0.0683	1.60
5.	Tăuții de Sus	5	0.0045	0.80	0.0090	1.60
		30	0.0239	0.80	0.0479	1.60
		50	0.0279	0.80	0.0559	1.60
		100	0.0300	0.80	0.6015	1.60
6.	Sighetu Marmăției	5	0.1212	2.00	0.2424	4.00
		30	0.1212	2.00	0.2424	4.00
		50	0.1212	2.00	0.2424	4.00
		100	0.1212	2.00	0.2424	4.00

In *Baia Sprie II*, on the one hand, a decrease in the transfer factor at 5 cm of 1.72 times is observed in the year 2024. On the other hand, at all sampling depths there is an increase of 1.53 times (30 cm) and 2 times (100 cm) in 2024 compared to 2023. For the mobile form, we have a 2-fold increase, with the baseline value being exceeded only in 2024.

In *Tăuții de Sus*, the transfer factor shows a 2-fold increase compared to the previous year, while at 100 cm a 20-fold increase is observed. Mobile transfer factor values are 2 times higher in 2024. Exceedances are recorded only in 2024 for the mobile transfer factor at all depths.

In *Sighetu Marmăției* (the control) we have a 2-fold increase in transfer factor for both total and mobile form. There were exceedances for the mobile form in both years of study at all depths.

CONCLUSIONS

Heavy metals content in the soil. We observe exceedances of the maximum admissible limits

for Pb in Baia Mare (30 cm, 50 cm, 100 cm), Baia Sprie I (5 and 30 cm), Baia Sprie II (5 cm) and Tăuții de Sus (5 cm and 30 cm). The highest value was recorded in Tăuții de Sus, and the limits exceeded in most samples was in the case of the Baia Mare sampling point, also known in the literature (Lăcătușu et al., 1996b; Ulmanu et al., 2006; Bora et al., 2020) as an intensely polluted area. For Cd in total form, we observe exceedances of the maximum permissible limits (in fewer cases than for Pb) at Baia Mare (30 cm and 100 cm) and Tăuții de Sus (5 cm) sampling points.

Heavy metal content in fruits. Concerning Pb content, the Romanian legislation is much more permissive (0.5 mg/kg) than the EU one (0.1 mg/kg), while for Cd the international legislation, namely Codex Alimentarius, is the most permissive (1-1.3 mg/kg), while both national and EU legislation (0.05 mg/kg) impose stricter maximum allowed limits. In 2023 there were no exceedances of the maximum allowable limits, but in 2024, the Pb content was of the international and European limit, but below the international threshold, and the Cd content was exceeded at the national and European level, but acceptable from the international point of view.

The transfer factor. The values in total form don't exceed the reference threshold (not greater than 1) which agrees with similar results reported by other authors (Mihali et al., 2013; Emurotu & Onianwa, 2017; Thien et al., 2021; Olusegun et al., 2023) and that a value greater than 1 was recorded in the case of the mobile fraction of Pb (Săbișa – 2023 - 30 cm and 50 cm, 2024 - all depth; Baia Mare – both years and both depth; Baia Sprie I – only at 100 cm in 2024; Baia Sprie II – 2024 – all depth; Tăuții de Sus – both years at 5 cm and Sighetu Marmăției – both years at all depth) and Cd (Săbișa and Baia Mare and Sighetu Marmăției – all depth and both years, Baia Sprie I, Baia Sprie II and Tăuții de Sus – only in 2024 at all depth).

Food safety remains an essential factor for both product quality and human health, thus maintaining its constant importance. At the same time, it is recommended to adopt a system of regular monitoring, since exceeding the maximum permissible limits can have negative effects on human health

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