

ASSESSMENT OF ELEMENT ACCUMULATION EFFICIENCY IN PLANT PARTS USING BIOLOGICAL FACTOR ANALYSIS

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Abstract

Understanding the processes of accumulation and translocation of potentially toxic elements through the soil-plant system is crucial for environmental protection and pollution risk assessment. The aim of this study is to investigate the possibility of accumulation and translocation of potentially toxic elements in *Crataegus* spp. and to assess the applicability of this plant species in phytoremediation.

Keywords: *Crataegus* spp., Biological factor analysis, potentially toxic elements

1. INTRODUCTION

Potentially toxic elements in the environment can originate from natural sources, such as volcanic activities, weathering of metal-rich rocks, erosion and other geological processes, as well as from human activities, such as industrial processes, urban wastewaters, agriculture, etc. [1]. Mining represents a significant source of environmental pollution. Once toxic elements enter the soil, they can be accumulated by crops, including vegetables and other plants. The uptake of potentially toxic elements by plants from the soil is an important pathway by which toxic elements can enter the food chain. Understanding the translocation and accumulation of elements in soils and plants is of great importance for environmental protection [2]. Phytoremediation is an environmentally friendly strategy to improve contaminated areas [3].

This study aims to evaluate the possibility of accumulation and translocation of potentially toxic elements in different parts of *Crataegus* spp. and its potential for use in phytoremediation.

2. EXPERIMENTAL

Crataegus spp., a widespread perennial deciduous shrub, was selected for investigation. The plant material (roots and leaves) and the soil from the root zone were sampled during the plant's harvest period, before natural leaf fall (September to mid-October). The sampled plants were healthy with no visible signs of disease or pests. The total of 14 sampling sites were distributed into eight sampling zones (urban-industrial (UI), urban (U), suburban (SU), industrial (I1, I2, I3, I4 and I5), rural (R1 and R2), tourist (T), traffic (TR) and background (B)). The locations of the sampling sites were selected in relation to the copper smelter, open pits, ore waste heaps, and the flotation tailing ponds. The B zone was located in the rural settlement of Gornjane, 17 km from the copper smelter, which was not affected by anthropogenic pollution [4,5]. A detailed description of the sampling procedure and the sampling sites can be found in Kalinović *et al.* [5].

Biological factor analysis is used to assess the ability of plants to accumulate potentially toxic elements from the soil and translocate them through the plant. Biological factor analysis is crucial in revealing the remarkable capabilities of plants, such as their potential for environmental

remediation. The bioconcentration factor (BCF) provides information about a plant's ability to accumulate elements from the soil in the roots. The factor is calculated using equation (1) [1,6,7]:

$$BCF = C_r / C_s \quad (1)$$

where C_r is the element concentration in the plant root (mg/kg); C_s is the element concentration in the soil (mg/kg). If the BCF value is greater than 1, the accumulation of elements in the plant roots is effective [1,6,7].

The translocation factor (TF) indicates the ability of plants to transport elements from the roots to the leaves (i.e. to allow them to enter the food chain). The factor is calculated according to the following equation (2) [1,6,7]:

$$TF = C_{wl} / C_r \quad (2)$$

where C_{wl} is the element concentration in the washed leaves (mg/kg); C_r is the element concentration in the plant root (mg/kg). If the TF value is greater than 1, the elements are effectively translocated within the plant [1,6,7].

The biological absorption coefficient (BAC) is calculated by the equation (3) [8,9]:

$$BAC = C_{wl} / C_s \quad (3)$$

where C_{wl} is the element concentration in the washed leaves (mg/kg); C_s is the element concentration in the soil (mg/kg).

Depending on the BAC values, the absorption of elements in leaves from the soil can be intensive (BAC in the range of 10–100), strong (1.0–10.0), intermediate (0.1–1.0), weak (0.01–0.10), and very weak absorption (0.001–0.010) [10]. According to Nouri *et al.* [11], plants suitable for phytoextraction generally have the values of $BCF > 1$ and $TF > 1$, whereas, plants suitable for phytostabilisation have $BCF > 1$ and $TF < 1$.

3. RESULTS AND DISCUSSION

The BCFs for As, Cd, Cu and Pb are shown in Table 1.

Table 1. Bioconcentration factor (BCF) for As, Cd, Cu and Pb

Site	As	Cd	Cu	Pb
UI	<0.006	<0.054	0.004	<0.008
U	<0.010	<0.085	0.006	<0.011
SU	<0.014	<0.103	0.007	<0.010
I1	<0.050	<0.435	0.032	<0.030
I2	<0.024	<0.299	0.099	0.039
I3	<0.057	<0.108	0.012	<0.015
I4	<0.025	<0.255	0.007	<0.025
I5	<0.029	<0.192	0.010	<0.027
R1	<0.012	0.730	0.043	<0.026
R2	0.011	0.413	0.040	0.026
T1	<0.008	<0.048	0.005	<0.012
T2	<0.007	0.267	0.049	0.055
TR	<0.086	<0.209	0.012	<0.016
B	<0.103	/	0.079	<0.053

The BCF values with the sign "<" are obtained by replacing the missing element concentration by the limit of determination of the element in the root (the LD for As and Pb is 1 mg/kg; for Cd 0.2 mg/kg); "/" Both values are missing in the calculation of the BCF.

The BCF values for all the analysed elements were below 1 at each sampling site (except at site B for Cd), indicating that *Crateaegus* spp. have a low ability to accumulate these elements in the roots from the soil.

Regardless of this, a significant correlation between the Cu concentrations in the soil and root samples (Table 2) indicates a possible accumulation of a certain amount of Cu from the soil. It was not possible to calculate the correlation for the other elements, as their concentrations were below the limit of determination for most samples.

Table 2. Spearman correlation coefficient

Element	Soil–Root	Root–Washed leaves	Soil–Washed leaves
As	/	/	0.727*
Cd	/	/	/
Cu	0.582*	0.820**	0.749**
Pb	/	/	0.429

** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed);
"/" The correlation coefficient was not calculated for the elements for which the number of samples is ≤ 5 .

The TFs for As, Cd, Cu and Pb are shown in Table 3. According to the obtained values, the TFs for the analysed elements were higher than 1 in most cases (except at the sites R1, R2 and T2 for Cd and at the site T2 for Cu). These high TF values indicate that *Crataegus* spp. effectively translocated the elements from the roots to the leaves. The significant and positive correlation between the Cu concentrations in the roots and the washed leaves is in favour of an effective translocation. However, it was not possible to calculate the correlations for the other elements as their concentrations were below the limit of determination for most samples.

Table 3. Translocation factor (TF) for As, Cd, Cu and Pb

Site	As	Cd	Cu	Pb
UI	>29.977	>2.596	9.225	>28.383
U	>2.463	/	3.588	>5.443
SU	>1.524	/	4.272	>3.902
I1	>1.474	/	5.279	>2.222
I2	>1.427	/	1.223	2.325
I3	/	/	3.286	>2.224
I4	>1.829	/	5.885	>4.712
I5	>2.027	/	4.813	>4.618
R1	>4.868	0.761	2.282	>10.325
R2	6.195	0.694	3.128	18.255
T1	>1.705	/	6.583	>8.549
T2	>2.628	<0.713	0.768	1.522
TR	/	/	1.152	>1.775
B	/	/	2.143	>1.198

The values given in bold represent $TF > 1$; The TF values with the sign ">" are obtained by replacing the missing element concentration by the limit of determination of the element in the root (the LD for As and Pb is 1 mg/kg; for Cd 0.2 mg/kg); "/" Both values are missing in the calculation of TF.

The BAC values for As, Cd, Cu and Pb are shown in Table 4. The determined values show a weak to intermediate absorption of the analysed elements from the soil into the leaves. A certain amount of the elements can also be absorbed from the air via the leaves. However, the significant and positive correlations between the elements in the soil and the washed leaves (except for Cd) shown in Table 2 confirm that *Crataegus* spp. absorb elements from the soil into the leaves via the roots to a certain extent. According to Baker's classification [12], *Crataegus* spp. could be categorised as an excluder due to the BAC values for As, Cd, Cu and Pb, which were below 1. Based on the values obtained for BAC and TF, it could be said that *Crataegus* spp. is unsuitable for phytoextraction or phytostabilisation of the studied elements. However, it is the plant that has adapted to the environment with different levels of pollution.

Table 4. Bioaccumulation factor (BAC) for As, Cd, Cu and Pb

Site	As	Cd	Cu	Pb
UI	0.182	0.140	0.041	0.237
U	0.025	<0.085	0.022	0.063
SU	0.023	<0.103	0.030	0.041
I1	0.075	<0.435	0.170	0.068
I2	0.036	<0.299	0.121	0.090
I3	<0.057	<0.108	0.041	0.035
I4	0.046	<0.255	0.042	0.121
I5	0.059	<0.192	0.049	0.125
R1	0.062	0.555	0.098	0.273
R2	0.067	0.286	0.125	0.472
T1	0.015	<0.048	0.033	0.107
T2	0.021	<0.191	0.038	0.084
TR	<0.086	<0.209	0.014	0.029
B	<0.103	/	0.170	0.064

The BAC values with the sign "<" are obtained by replacing the missing element concentration with the limit of determination of the element in the washed leaves (the LD for As is 1 mg/kg; for Cd 0.2 mg/kg); "/" Both values are missing in the calculation of BAC.

4. CONCLUSIONS

In this study, the accumulation and translocation of potentially toxic elements in *Crataegus* spp. were analysed. The results showed that this plant species has a low ability to accumulate As, Cd, Cu and Pb from the soil into the roots. In addition, *Crataegus* spp. has a limited potential for the translocation of these elements to the aboveground parts of the plant. Therefore, *Crataegus* spp. is not considered suitable for phytoextraction or phytostabilisation purposes.

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