*Original Article*

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# Investigation of the Biogeochemical Anomalies of *Euphorbia cyparissias* plant in Gümüshacıköy—Amasya Pb-Zn-Ag Deposits, Turkey

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**Abstract**

The study area is located in Çorum G34 a3 and a4 section in Gümüşhacıköy (Amasya). 17 samples of *Euphorbia cyparissias* plant grown in this region and related soil samples were collected and analyzed. The metal content of the investigated soil samples is as follows: Fe > Zn > As > Mn > Pb > Cu > Sb > Cr >> Ag > Ni > Co > Cd. The soil pH controlling the metal transfer in the soil, the pH values of the examined soil samples are between 4.66 and 8.22. This range indicates that the soil samples are in acidic and basic conditions. Metal pollution (toxicity) due to increased mining activities may affect the environment and public health. The correlation coefficient was a strong positive correlation between Ni with Co and Ag, As with Sb (0.89); Ni (0.88) and Cu (0.86), Pb with Co (0.84), Cu (0.81), Ni (0.85) and Sb (0.81), Ni with Cu (0.81) and Sb (0.86), while there is a negative correlation between Mn with Ag, As, Cd, Co, Cr, Ni, Sb and Pb, and Fe with Cd, Co, Cr, Ni and Pb. The bioaccumulation factor (BAC) values of *Euphorbia cyparissias* have been found between not accumulate— high accumulator or hyperaccumulator plants in both root/soil and leaf/soil. The translocation factors (TF) of all metals (10 in location), Cr and Ni (3 in location), Co, Cu, Mn and Zn in the (9 in location), Ni (11 in location), and Cd, Co, Cr, and Ni values (16 in location) are less than 1. TF values calculated outside these locations are greater than 1. TF values greater than 1 showed that the metal concentration in the leaves was higher than the roots.

**Keywords:** *Euphorbia cyparissias*; Translocation; Bioaccumulation; Metal pollution (toxicity).

## Introduction

Metals caused by increased mining activities cause soil, water and air pollution.[1–6] If the pollution caused by metals is not taken immediately, it can affect the environment and public health.[2,4,7] The toxicity of the heavy metals can be a serious threat to human health due to its persistence and failure.[8,7]

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Remediation of soils contaminated by metals is one of the important issues of environmental restoration today.[5] The present application for the treatment of soils contaminated with heavy metals is the decontamination of the soil.[9] Since the extraction with chemicals is expensive and applied only for small areas, it is necessary to apply decontamination.[9–11] This process often causes adverse effects on biological activities, soil structure and fertility.[9] Recently developments in the field of environmental improvement have revealed the phytoremediation technique.[12] This method requires a low technology, can be performed in situ and used for decontamination of a specific area. It also protects the biological properties and physical structure of the soil, it is an inexpensive method.[13] An effective phytoremediation depends on the selection of local plant species and the hyperaccumulative properties such as the age, texture and structure of the soil contaminated by metals.[2,9,11,14]

Soil is the most important source of trace metals (such as cadmium, chromium, lead, nickel, silver and zinc) that reach living beings (humans, plants and animals).[15] The trace elements content in the soil varies according to the composition of the rocks, slag, waste water, industrial wastes and the amount of fertilizer used in agriculture.[16] Although living things need some metals to live well, they can have negative effects on their health when they take these metals excessively.[15–19]

Lead (Pb), cadmium (Cd) and zinc (Zn) can occur simultaneously in high concentrations as a result of mining and smelting operations.[20] Zn, an important metal for the development of plants Zn, has a toxic effect in high concentrations. Zn usefulness for plants is quite narrow.[21,22] Pb and Cd are not essential elements for the growth of plants. These elements may cause negative effects on the prevention of photosynthesis and chlorophyll synthesis of plants, and finally plants may death.[23,24]

Investigation of the biogeochemical anomalies of *E. cyparissias* plants was the aim of this study. It is also aimed to determine the accumulation and distribution of metals in the roots and leaves of *Euphorbia cyparissias* plant growing in Pb-Zn-Ag deposits was of Gümüshacıköy region in Amasya, Turkey. In addition, TF and BAC values were calculated to determine if there was an accumulator in the study area of this plant.

### *Geology of the Study Area*

Pb-Zn-Ag deposits are located on the west of Gümüşshacıköy district of Amasya (Fig. 1), Corum G34, a3 and a4 section. Gümüshacıköy (Amasya) Pb-Zn-Ag deposits offer extrusion in many units from Permo-Triassic to Quaternary (Fig. 2). These beds in the study area show three different bedding patterns in carbonated rocks within the Karaali Complex (Upper Jurassic-Lower Cretaceous). These: (a) in the form of irregular pockets and scatterings in siliceous carbonated travertines deposited along the limestone—sandstone contact, (b) fracture zones in limestone blocks and vein—type occurrences in dissolution cavities, (c) in the limestone blocks, parallel to the plate planes.[25]


**Source:** Google map
**Fig. 1:** Location map of the study area.

As a result of the geochemical investigations, the Pb and Zn contents of the tuffs in the volcanic rocks in Karaali Karlukı and the Cu contents of the metabasalts were higher than the other rock types. Although Ag minerals are low in the ore samples, the high content of Ag in chemical analyzes shows that this metal is taken to replace Pb in galena. In addition, although Cd minerals were not detected, the high Cd content in the samples was considered to be enriched in sphalerites in this metal. All the data were evaluated together and it was concluded that the mineralizations in the region were due to the formation of siliceous-carbonate travertines, and they were probably formed by hydrothermal processes in recent days. The properties of the ore-forming solutions and the origins of the water and the metals in the hydrothermal solutions could not be obtained (Fig. 2).[25]

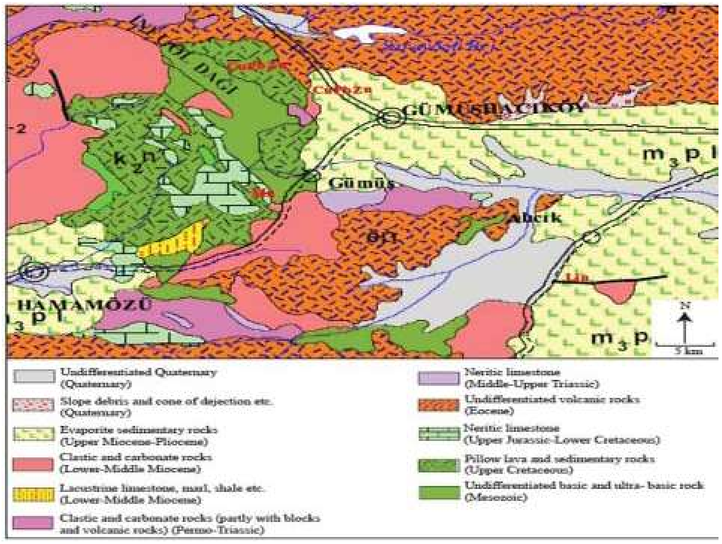


**Fig. 2**: Geological map of the study area (modified from[55]).

## Sampling and Analysis Methods

### *Plant*

Seventeen *Euphorbia cyparissias* plant samples were randomly collected from the study area and placed in pre-numbered plastic bags and brought to the laboratory (Fig. 3). After washing with pure water, these samples were separated into leaves and roots and dried at room temperature. These dried plant bodies were incinerated in flames at temperatures from 50°C to 550°C at intervals of one hour (Fig. 3).

**Fig. 3:** Burning and ashing of dried plant organs in the furnace.

### *Soil*

A total of 17 samples were collected from the soil of 10–15 cm depth where *Euphorbia cyparissias* grown on the plant. All soil samples were stored in plastic bags and numbered and brought to the laboratory. These samples brought to the laboratory were dried at room temperature and –80 mesh sieves to remove them from the coarse rock fragments and plant roots.

Sample tubes were prepared by mixing 4 g of soil with 10 ml of pure water to measure the pH values of soil samples. pH values were measured by using pH meter.[26,27] (Fig. 3).

0.1 g of the obtained plant ash and soil samples were taken into solution by adding 3 ml $HNO_3$ and 6 ml HCl at 200°C in closed environment.[28] Ag, As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Sb and Zn were analyzed by ICP-MS. The analyzes were conducted at Yozgat Bozok University Technology Application and Research Center. LOD values (ppb); Al: 0.3687, Ag: 0.0155, As: 0.0386, Au: 0.0027, Ba: 0.0108, Cd: 0.0049, Co: 0.0084, Cr: 0.0474, Cu: 0.0252, Fe: 0.7846, Mg: 0.0211, Mn: 0.0307, Mo: 0.0097, Ni: 0.2135, Pb: 0.0138, Sb: 0.0068, Se: 0.1192, Th: 0.0042, Ti: 0.0406, U: 0.0011, V: 0.0275 and, Zn: 0.0904

### *Statistical analysis*

Correlation coefficient ($r$) measures linear dependence between two data sets or two variables. $r$ = 1 indicates an excellent positive correlation and $r$ = –1 indicates a negative correlation.[29]

The calculated probability ($p$) is considered as statistically significant when $p < 0.05$ (2-tailed).[30,31] Sperman correlation analyses were made using SPSS 15.0 for Windows Evaluation Version.

### *Translocation factor (TF)*

Metal translocation from leaf to root was measured by the following Translocation factor (TF):

$$TF = C_{leaf}/C_{root}$$

Where $C_{leaf}$ and $C_{root}$ are metals concentration in the leaf (mg/kg) and root of plant (mg/kg), respectively. TF > 1 indicates that the translocation of metals is effectively performed from the root to the leaf.[31–36]

### *Bioaccumulation factor (BAC)*

The bioaccumulation factor (BAC) of the metals was calculated as follows:

$$BAC=C_{root}/C_{soil} \text{ or } BAC=C_{leaf}/C_{soil}$$

$C_{root}$, $C_{leaf}$ and $C_{soil}$ are the metal concentration in the root (mg/kg) and leaf (mg/kg) of the plant and in the soil (mg/kg), respectively.[35,37,38]

Metal accumulation is described under four categories. These:

(1) <0.01, plants without accumulator,

(2) 0.01–0.1, low degree of accumulator plants,

(3) 0.1–1.0, medium accumulator plants,

(4) 1–10, highly accumulating or hyper-accumulating plants. By using this ratio, the absorption of the metals in the soil can be shown and the magnitude of the metal transition from soil to plant can be estimated quantitatively.[39]

## Results and Discussion

Table 1 shows the minimum, maximum and mean ± standard deviation descriptive statistics of the metal concentrations in the samples collected in the study area. The metal contents in the soil are as follows: Fe > Zn > As > Mn > Pb > Cu > Sb > Cr > Ag > Ni > Co > Cd (Table 1). Soil pH is an indicator of various chemical activities and the pH values of the soil samples examined are given in Table 1. pH values range from 4.66 to 8.22. This range shows that the soil samples are in acidic, neutral and basic conditions. Suitable for plant growth, pH values are between 5.2–7.3. Soil pH is a parameter that controls metal transfer in soils. The decrease in pH in soil increases competition between $H^+$ and dissolved metals such as $CO_3^{2-}$, $SO_4^{2-}$, $Cl^-$, $OH^-$, $S^{2-}$ and phosphates.[5] This increased competition reduces the metal adsorption capacity in the soil and increases the mobility of metals. This increase in mobility increases the bioavailability of metals in soil.[14]

**Table 1:** The minimum, maximum and mean ± standard deviation descriptive statistics of the metal concentrations

| Metals | Minimum | Maximum | Median ± St. Deviation |
|---|---|---|---|
| Ag | 0.07 | 0.93 | 0.205 ± 0.21 |
| As | 7.65 | 258.42 | 68.94 ± 73.65 |
| Cd | 0.00 | 0.09 | 0.013 ± 0.03 |
| Co | 0.01 | 0.12 | 0.052 ± 0.04 |
| Cr | 0.18 | 0.64 | 0.36 ± 0.14 |
| Cu | 0.78 | 13.18 | 3.58 ± 2.88 |
| Fe | 846.20 | 2483.7 | 1659.81 ± 492.7 |
| Mn | 26.64 | 257.14 | 56.51 ± 61.93 |
| Ni | –0.01 | 0.54 | 0.16 ± 0.17 |
| Sb | 0.42 | 7.18 | 2.94 ± 2.19 |
| Pb | 34.74 | 141.45 | 68.19 ± 28.84 |
| Zn | 21.38 | 503.37 | 69.4 ± 108.17 |

While there is a positive correlation between all metals examined (Ag, As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Sb, Pb and Zn, $p < 0.05$ significant), there is a negative correlation between Mn with Ag, As, Cd, Co, Cr, Ni, Sb and Pb, and Fe with Cd, Co, Cr, Ni and Pb (Table 2).

The correlation coefficient between Co and Ni was 0.93, indicating a strong positive correlation at the level of significance of 0.01 and a commen origin of these metals. Arsenic showed strong positive correlations with Sb (0.89) Ni (0.88) and Cu (0.86). Pb showed strong positive correlation with Co (0.84), Cu (0.81), Ni (0.85) and Sb (0.81). Ni showed strong positive correlation with Cu (0.81) and Sb (0.86). Ag and Ni suggest that it is probably due to a common origin and formed a pair with a highly positive correlation with 0.81 correlation coefficient (Table 2).

**Table 2:** Sperman correlation coefficient values of metal concentrations in soil.

| | Ag | As | Cd | Co | Cr | Cu | Fe | Mn | Ni | Sb | Pb | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ag | 1 | | | | | | | | | | | |
| As | .787(**) | 1 | | | | | | | | | | |
| Cd | 0.395 | .545(*) | 1 | | | | | | | | | |
| Co | .647(**) | .779(**) | .636(**) | 1 | | | | | | | | |
| Cr | 0.48 | 0.323 | 0.263 | .618(**) | 1 | | | | | | | |
| Cu | .674(**) | .860(**) | .580(*) | .796(**) | 0.179 | 1 | | | | | | |
| Fe | –0.458 | –0.458 | –.663(**) | –.683(**) | –.747(**) | –0.36 | 1 | | | | | |
| Mn | –.608(**) | –.581(*) | –.687(**) | –.625(**) | –.611(**) | –0.414 | .672(**) | 1 | | | | |
| Ni | .814(**) | .880(**) | .549(*) | .926(**) | .589(*) | .811(**) | –.634(**) | –.635(**) | 1 | | | |
| Sb | .790(**) | .893(**) | .647(**) | .771(**) | 0.253 | .798(**) | –0.38 | –.656(**) | .856(**) | 1 | | |
| Pb | .799(**) | .752(**) | .783(**) | .840(**) | 0.459 | .806(**) | –.694(**) | –.686(**) | .845(**) | .808(**) | 1 | |
| Zn | –0.353 | –0.382 | –0.114 | –0.401 | –.642(**) | –0.142 | 0.424 | .618(**) | –0.358 | –0.276 | –0.24 | 1 |

Show that it is correlation between these metals is related to the presence of primary minerals such as sphalerite, galena, fahlerz, pyrite, chalcopyrite and pyrrhotite and secondary minerals occurring under surface conditions such as covelline, pyroluzite, marcasite, sericite, anglezite, calcophanite-aurorite, goethite, limonite and gypsum in the study area.[25]

The bioaccumulation factors of the metals in the plant of *Euphorbia cyparissias* are shown in Table 3–4. In this table, the bioaccumulation factor values of Cd (1, 4, 10, 14, 15 and 17 locations), Ni (2 and 13 in locations) and Sb (4 in locations) in the roots, and As (2, 3, 4 and 13 in locations), Cd (1-4 and 13-17 in locations), Co (2-4, 13 and 15-17 in locations), Cr (2 in locations), Ni (2-4, 13 and 15-17 in locations, Sb (2–4, 13 and 17 in locations) and Pb (3 in locations) in the leaves of *Euphorbia cyparissias* plant are greater than 1.

*Euphorbia cyparissias* plant BAC values (root/soil), Ag (0.01-0.30), Cu (0.01–0.78) and Pb (0.01–0.42) metals in class of low accumulator— medium accumulator plants; Co (0.00–0.73), Fe (0.00–0.14), Mn (0.00–0.16) and Zn (0.00–0.31) metals, in class of non-accumulator—medium accumulator plants, and Ni (0.01–1.10) metal are found in the class of low accumulator— high accumulator or hyperaccumulative plants (Table 3).

**Table 3:** Bioaccumulation factor (BAC) of metal accumulations in soil (root/soil)

| | Ag | As | Cd | Co | Cr | Cu | Fe | Mn | Ni | Sb | Pb | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.02 | 0.02 | 1.25 | 0.08 | 0.08 | 0.02 | 0.02 | 0.02 | 0.06 | 0.03 | 0.13 | 0.04 |
| 2 | 0.10 | 0.19 | 0.91 | 0.21 | 0.15 | 0.07 | 0.01 | 0.00 | 1.00 | 0.18 | 0.08 | 0.02 |
| 3 | 0.02 | 0.02 | 0.33 | 0.03 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.07 | 0.03 | 0.01 |
| 4 | 0.30 | 0.52 | 6.67 | 0.73 | 0.26 | 0.38 | 0.08 | 0.05 | 0.73 | 1.10 | 0.42 | 0.17 |
| 5 | 0.15 | 0.12 | 0.32 | 0.22 | 0.14 | 0.20 | 0.14 | 0.16 | 0.26 | 0.21 | 0.23 | 0.20 |
| 6 | 0.07 | 0.05 | 0.16 | 0.16 | 0.08 | 0.14 | 0.03 | 0.05 | 0.11 | 0.05 | 0.07 | 0.04 |
| 7 | 0.05 | 0.03 | 0.72 | 0.13 | 0.03 | 0.18 | 0.01 | 0.03 | 0.13 | 0.04 | 0.06 | 0.04 |
| 8 | 0.05 | 0.11 | 0.24 | 0.15 | 0.19 | 0.19 | 0.12 | 0.15 | 0.30 | 0.12 | 0.12 | 0.20 |
| 9 | 0.17 | 0.04 | 0.96 | 0.08 | 0.02 | 0.78 | 0.04 | 0.12 | 0.05 | 0.04 | 0.06 | 0.31 |
| 10 | 0.17 | 0.06 | 1.57 | 0.17 | 0.13 | 0.29 | 0.07 | 0.11 | 0.12 | 0.06 | 0.15 | 0.27 |
| 11 | 0.03 | 0.01 | 0.19 | 0.02 | 0.00 | 0.19 | 0.01 | 0.02 | 0.00 | 0.03 | 0.03 | 0.12 |
| 12 | 0.07 | 0.04 | 0.29 | 0.04 | 0.02 | 0.09 | 0.02 | 0.02 | 0.03 | 0.04 | 0.07 | 0.06 |
| 13 | 0.13 | 0.25 | 0.40 | 0.16 | 0.05 | 0.09 | 0.01 | 0.01 | 1.00 | 0.12 | 0.08 | 0.00 |
| 14 | 0.07 | 0.25 | 1.67 | 0.26 | 0.02 | 0.13 | 0.01 | 0.02 | 0.17 | 0.12 | 0.15 | 0.04 |
| 15 | 0.14 | 0.20 | 2.29 | 0.43 | 0.07 | 0.22 | 0.02 | 0.01 | 0.75 | 0.10 | 0.21 | 0.06 |
| 16 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 |
| 17 | 0.04 | 0.05 | 2.00 | 0.43 | 0.03 | 0.23 | 0.00 | 0.01 | 0.00 | 0.08 | 0.07 | 0.08 |

In terms of metal accumulation, Pb (41, 42) and Cd are a risky heavy metal for the environment and living organisms.[26] Cd (0.00–6.67) are included in the class of non accumulator—high degree accumulator or hyperaccumulative plants. In the study area, Cd (0.00–6.67), has a high accumulation of accumulators or hyperaccumulators at 6 sampling locations (Table 3).

In the study area, the BAC of As metal is between 0.01–0.52 mg/kg and it is in the class of accumulator in the low - medium level (Table 3).

*Euphorbia cyparissias* plant BAC values (leave/soil), Ag (0.05-0.96), Fe (0.03-0.29), Mn (0.03-0.39) and Zn (0.03-0.84) metals in class of low accumulator— medium accumulator plants; As (0.02–2.56), Co (0.07–4.57), Cr (0.02–1.05), Ni (0.02-12.0), Sb (0.03–4.71) and Pb (0.05–1.07) metals in class of low accumulator— high accumulator or hyperaccumulative plants; Cd (0.19–10.0) and Cu (0.11–2.05) metals in class of medium accumulator —high accumulator or hyperaccumulative plants (Table 4).

**Table 4:** Bioaccumulation factor (BAC) of metal accumulations in soil (leave/soil)

| | Ag | As | Cd | Co | Cr | Cu | Fe | Mn | Ni | Sb | Pb | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.14 | 0.30 | 8.75 | 0.79 | 0.63 | 0.20 | 0.28 | 0.27 | 0.50 | 0.31 | 0.71 | 0.43 |
| 2 | 0.80 | 2.36 | 2.09 | 1.33 | 1.05 | 0.53 | 0.10 | 0.04 | 12.00 | 1.79 | 0.52 | 0.16 |
| 3 | 0.69 | 1.89 | 10.00 | 1.88 | 0.32 | 0.81 | 0.17 | 0.14 | 1.83 | 4.71 | 1.07 | 0.38 |
| 4 | 0.59 | 1.31 | 8.00 | 1.25 | 0.26 | 0.75 | 0.18 | 0.13 | 1.55 | 2.15 | 0.74 | 0.33 |
| 5 | 0.51 | 0.34 | 0.79 | 0.65 | 0.26 | 0.60 | 0.29 | 0.39 | 0.74 | 0.55 | 0.72 | 0.57 |
| 6 | 0.28 | 0.23 | 0.40 | 0.48 | 0.19 | 0.34 | 0.11 | 0.18 | 0.52 | 0.27 | 0.43 | 0.19 |
| 7 | 0.26 | 0.23 | 0.94 | 0.50 | 0.10 | 0.32 | 0.07 | 0.10 | 0.63 | 0.25 | 0.40 | 0.13 |
| 8 | 0.15 | 0.23 | 0.28 | 0.57 | 0.39 | 0.38 | 0.24 | 0.35 | 0.63 | 0.29 | 0.27 | 0.40 |
| 9 | 0.09 | 0.09 | 0.19 | 0.08 | 0.02 | 0.29 | 0.08 | 0.10 | 0.05 | 0.09 | 0.08 | 0.17 |
| 10 | 0.05 | 0.02 | 0.29 | 0.07 | 0.03 | 0.11 | 0.03 | 0.05 | 0.02 | 0.03 | 0.05 | 0.09 |
| 11 | 0.10 | 0.07 | 0.29 | 0.09 | 0.04 | 0.52 | 0.05 | 0.06 | 0.13 | 0.07 | 0.09 | 0.23 |
| 12 | 0.44 | 0.37 | 0.82 | 0.29 | 0.11 | 0.64 | 0.19 | 0.20 | 0.38 | 0.39 | 0.39 | 0.40 |
| 13 | 0.96 | 2.56 | 1.70 | 1.26 | 0.32 | 0.55 | 0.06 | 0.07 | 9.00 | 1.21 | 0.61 | 0.03 |
| 14 | 0.14 | 0.82 | 2.67 | 0.74 | 0.09 | 0.45 | 0.04 | 0.06 | 0.58 | 0.35 | 0.31 | 0.14 |
| 15 | 0.50 | 0.74 | 4.71 | 1.35 | 0.21 | 0.74 | 0.07 | 0.03 | 2.50 | 0.32 | 0.63 | 0.24 |
| 16 | 0.50 | 0.51 | 2.08 | 1.05 | 0.33 | 0.48 | 0.06 | 0.07 | 3.00 | 0.54 | 0.42 | 0.13 |
| 17 | 0.33 | 0.99 | 7.33 | 4.57 | 0.24 | 2.05 | 0.05 | 0.15 | 11.00 | 1.26 | 0.81 | 0.84 |

As a result, the plants analyzed in this study can be said to be contaminated with Cd and Sb. As a result, these metals can be transferred to the food chain.[26,30,41]

Arsenic (As) is an important pollutant in the world. The BAC for As is about 5 mg/kg in uncleaned soils,[26,42,43] however, this value is between 1400 and 2700 mg/kg in polluted soils.[26,45]

Manganese is one of the most essential nutrients for plants.[40] Although the known botanical function of nickel is not known, copper, zinc and iron are essential metals for plants, but they may be toxic in high concentrations.[45]

The metals are usually found in roots and leaves.[46] Plant metals take place with metals accumulation of metals. Therefore, the roots of the *Euphorbia cyparissias* plant can prevent the spread of heavy metals into the environment. Metal contaminants in high concentrations in soils can be stored in the leaves of this plant.[47,48]

The Translocation Factor (TF) was calculated as the ratio of the total metal concentration in the leaves to the metal content in the roots.[45]

The TF of metals in *Euphorbia cyparissias* plants are shown in Table 5. In this table, the translocation factors of all metals in the location 10, Cr and Ni in the location 3, Co, Cu, Mn and Zn in the location 9, Ni in the location 11, and Cd, Co, Cr, and Ni values in the location 16 are less than 1. The TF of the metals examined in all other locations are greater than 1. The fact that this factor is greater than 1 indicates that it can carry the metals from the roots to the leaves.[48]

**Table 5:** Translocation factor (TF) of metal accumulations in soil

| | Ag | As | Cd | Co | Cr | Cu | Fe | Mn | Ni | Sb | Pb | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6.40 | 15.78 | 7.00 | 9.44 | 8.00 | 8.45 | 14.42 | 11.41 | 9.00 | 10.24 | 5.62 | 10.31 |
| 2 | 8.33 | 12.62 | 2.30 | 6.33 | 7.00 | 7.96 | 9.27 | 10.10 | 12.00 | 9.92 | 6.18 | 9.28 |
| 3 | 40.0 | 94.5 | 30.0 | 64.0 | 0.00 | 66.3 | 92.1 | 74.7 | 0.00 | 66.0 | 42.0 | 64.9 |
| 4 | 1.97 | 2.49 | 1.20 | 1.72 | 1.00 | 1.97 | 2.19 | 2.65 | 2.13 | 1.95 | 1.75 | 2.02 |
| 5 | 3.44 | 2.76 | 2.50 | 2.96 | 1.88 | 2.94 | 2.08 | 2.39 | 2.88 | 2.64 | 3.18 | 2.85 |
| 6 | 4.17 | 5.14 | 2.57 | 3.00 | 2.33 | 2.45 | 4.36 | 3.28 | 4.67 | 5.04 | 6.11 | 4.47 |
| 7 | 5.20 | 7.23 | 1.31 | 3.71 | 3.00 | 1.75 | 6.18 | 3.23 | 5.00 | 6.77 | 6.44 | 3.10 |
| 8 | 3.03 | 2.09 | 1.14 | 3.92 | 2.00 | 2.02 | 1.93 | 2.41 | 2.11 | 2.30 | 2.27 | 2.06 |
| 9 | 0.52 | 2.51 | 0.20 | 0.90 | 1.00 | 0.37 | 2.16 | 0.85 | 1.00 | 2.14 | 1.22 | 0.55 |
| 10 | 0.29 | 0.45 | 0.18 | 0.39 | 0.25 | 0.40 | 0.41 | 0.41 | 0.20 | 0.47 | 0.34 | 0.35 |
| 11 | 4.00 | 4.80 | 1.50 | 4.00 | 0.00 | 2.79 | 4.37 | 3.25 | 0.00 | 2.33 | 3.07 | 1.96 |
| 12 | 5.94 | 9.96 | 2.85 | 6.80 | 7.00 | 6.76 | 8.86 | 8.36 | 13.00 | 8.79 | 5.81 | 7.08 |
| 13 | 7.22 | 10.20 | 4.25 | 8.00 | 6.00 | 6.33 | 10.34 | 10.15 | 9.00 | 10.25 | 7.78 | 7.92 |
| 14 | 1.95 | 3.28 | 1.60 | 2.83 | 4.00 | 3.56 | 2.97 | 3.68 | 3.50 | 2.81 | 2.11 | 3.92 |
| 15 | 3.45 | 3.64 | 2.06 | 3.10 | 3.00 | 3.38 | 3.71 | 3.96 | 3.33 | 3.33 | 3.08 | 4.11 |
| 16 | 35.5 | 84.6 | 0.00 | 0.00 | 0.00 | 52.0 | 94.1 | 88.7 | 0.00 | 73.0 | 40.9 | 58.9 |
| 17 | 7.6 | 20.6 | 3.7 | 10.7 | 8.00 | 8.9 | 18.8 | 12.3 | 11.0 | 16.0 | 12.0 | 11.0 |

The translocation of metals from the roots to the upper organs is a very important physiological process to remove the contaminated areas. [45,49–53]

The TF for metals in plants must be more than one to be considered as bioaccumulators.[47] Accumulators plants can accumulate metals in high concentrations in the above ground organs.[32] The *Euphorbia cyparissias* plant has high leaf/root translocation factors, except for some sample locations. The leaf/root translocation values greater than 1 showed that the metal concentration in the leaves was higher than in the roots. The translocation of metals in plants occurs with vascular system or xylem tissue. For plants, metal translocations of the essential metals (Cu, Fe, Mn and Zn) from roots to leaves were higher compared with the non-essential metals (As, Cd, Sb and Pb). The low translocation factors of non-essential metals show that *Euphorbia cyparissias* use these metals for both metabolic activity and growth, whereas the essential metals have higher mobility to the leaves. Lead is a toxic metal for the synthesis of photosynthesis of leaves, chlorophyll and antioxidant enzymes. Most of the time, the roots prevent the transport of non-essential metals to accumulate metals in the roots.[20,48]

## Conclusion

In this study, the biogeochemical anomalies of metal/trace metals in soils and in leaves and roots of Euphorbia cyparissias plant were investigated in Pb-Zn-Ag deposits was of Gümüshacıköy region in Amasya, Turkey. In this study, concentrations of metals such as: Ag, As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Sb and Zn, and the accumulation and distribution of these metals in the soil contents and in leaves and roots of *Euphorbia cyparissias* plant were determined. The order of metals in the soil; Fe > Zn > As > Mn > Pb > Cu > Sb > Cr > Ag > Ni > Co > Cd.

In the *Euphorbia cyparissias* plant (root/soil), Ag, Cu and Pb are classified as low accumulator-medium accumulator plants; Co, Fe, Mn and Zn were found in the class of non-accumulator-medium accumulator plants, Cd in the class of non– accumulator-high accumulator or hyperacumulative plants, and Ni in the class of low accumulator-high accumulator or hyperacumulative plants. In the *Euphorbia cyparissias* plant (root/soil), Ag, Fe, Mn and Zn are classified as low accumulator– medium accumulator plants; As, Co, Cr, Ni, Sb and Pb in the class of low accumulator - high accumulator or hyperacumulative plants, Cd and Cu in the class of medium accumulator-high accumulator or hyperacumulative plants.

Ag, As, Cu, Mn and Zn metals (2 in the different located), Fe, Pb, Sb Cd and Co metals (1 in the located), and Cr and Ni metals (4 in the different located) TF values 1 is smaller than. Other metal values outside these locations are greater than 1. The TF value greater than 1 indicates that the metal concentration in the leaves is higher than the roots and that the metals are transfered from the roots to the leaves.

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