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Original Article

Mineral and heavy metal concentration of nutritionally and therapeutically valued wild plants: Insights into health effects

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ABSTRACT

Background and Aims: The purpose of the study was to determine the concentrations of minerals and heavy metals in nutritive and therapeutically valued wild plants *Allium orientale* Boiss., *Eremurus spectabilis* M. Bieb., *Anchusa officinalis* L. and *Arum elongatum* Steven.
Methods: The presence and quantity of 23 minerals and heavy metals were analyzed by inductively coupled plasma mass spectrometry (ICP-MS).
Results: The most common minerals were P, Mg, K, Ca, Fe and Al. Moderately abundant elements were Na, Sr, Zn, Cu, Mn, B and Ni. Toxic heavy metals such as Sn, Li, Co, Se, Sb, Hg, Cd, As and Pb were present at very low concentrations or were not detected. *A. officinalis* was observed to be rich in K (7496.435 mg/kg) and Ca (2947.378 mg/kg). On the other hand, Fe concentrations were high in *A. orientale* (1022.068 mg/kg) and *A. elongatum* (699.932 mg/kg). The Mg concentration in *A. orientale* (731.012 mg/kg) was almost double that in the other three plants. Al was found in high concentrations in *A. orientale* (889.368 mg/kg) and *A. elongatum* (651.570 mg/kg). Cr concentration of *A. orientale, A. officinalis* and *A. elongatum* exceeded both EPA limits and standard concentrations in plants.
Conclusion: The study reveals the elemental profile, heavy metal content and possible effects on human health of four wild plants that are frequently used in alternative medicine and nutrition. Most of the elements are not at detrimental levels. Additionally, the results can be useful for the food and pharmaceutical industries and to guide nutritional and comparative studies.
Keywords: Edible wild plant, Mineral, Heavy Metal, Nutrition, Medicinal plant

INTRODUCTION

Minerals are the basic nutritional elements involved in the balancing of body fluids, the functioning of the nervous system, homeostasis, the functioning of enzymes and hormones, bones, teeth, muscles, blood formation and many other functions. Even at threshold levels, most minerals contribute significantly to normal growth and play important roles in biochemical functions and enzyme systems (Bhat, Kiran, Arun, & Karim, 2010). Element uptake of plants from the soil is selective, but as the level of essential elements in the soil increases, the uptake of heavy metals by plant tissues increases, and these heavy metals are indirectly involved in the food chain. C, H, O, N, P, K, S, Ca, Mg, Fe, Zn, Mn, Cu, B, Cl and Mo are essential elements for plants, and the elements Co, Al, Na, Si, Ni and V are considered necessary for some specific plants and some specific processes (Okcu, Tozlu, Kumlay, & Pehluvan, 2009).

Although more than sixty elements are considered heavy metals, the most well-known ones are Hg, Mn, Fe, Co, Ni, Cu, Zn, Cd, As, Cr, Pb, Ag, Sn and Se. However, Fe, Mn, Cu, Ni and Zn heavy metals are also known as essential heavy metals for the body.

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For this reason, their effects on the body are closely related to their concentrations in the edible parts of the plants. While decreasing the amounts of these essential elements can cause significant symptoms in the body, it can also cause toxicity in people who accumulate them at excessive levels (Okcu et al., 2009). Ba, Ag, Cu, Cr, Ni, Hg, Pb, Cd, Se and As are known to be the most toxic heavy metals for the human body, The main reasons for their toxic effects on the human body are mainly related to disorders of the intracellular metabolic processes, such as DNA, RNA, ATP damage, organelle and cell membrane damage, biomolecular degradation, enzyme inactivation, mitochondrial damage, apoptosis, organ failure, autoimmune diseases, and neurological disorders (Jaishankar, Tseten, Anbalagan, Mathew, & Beeregowda, 2014).

Even though research on wild edible plants primarily focuses on the medicinal and ethnobotanical properties of plants, studies on gastronomy tourism, nutritional values, and culinary uses have gained momentum recently. Knowing the benefits and harms of wild plants by obtaining information about their nutritional and therapeutic properties provides benefits for human health. Recently, a lot of research has been done to determine the mineral and heavy metal content of nutritional and medicinal plants (Aberoumand & Deokule, 2009; Bedassa, Abebaw, & Desalegn, 2017; Bhat et al., 2010; Ceylan & Alıc, 2015; Maharia, Dutta, Acharya, & Reddy, 2010; Muhammad, Shah, & Khan, 2011). As known for centuries, wild plants have been used as traditional medicines for the treatments such as hemorrhoids, diabetes, peptic ulcer, skin diseases, burns, kidney diseases, ringworm, digestive system diseases, colds, flu, cough, depression, fear, stress, nervous disorder and bronchitis. They are also thought to have important effects such as kidney stone reducer, milk increaser, menstrual remover, cholesterol lowering, snake and scorpion antidote and pain reliever.

The distributions of the four edible wild plants that make up the study material are as follows. *Allium orientale* (Eastern onion), is native to the East Mediterranean, Egypt, Levant, Libya, Cyprus, Sinai and Turkiye and is a species in the Alliaceae family. *Eremurus spectabilis* (Foxtail Lilly) member of the Liliaceae family is native to Turkiye, Iran, Lebanon, Iraq, Ukraine, Syria, North Caucasus, Palestine, southern Russia, Transcaucasia and Turkmenistan. *Anchusa officinalis* (Alkanet) is a species belonging to the family Boraginaceae whose native range extends from Europe to the Caucasus. *Arum elongatum* (Cuckoo pint) is a species in the Araceae family and distributed in Turkiye, Bulgaria, Ukraine, Greece, Palestine, Crimea, southern Russia, the North Caucasus and Transcaucasia (Karahan et al., 2020; Kardaş, 2019). The main objective of the present study is to determine the concentration of minerals and heavy metals in the therapeutic and nutritional wild plants *A. orientale, E. spectabilis, A. officinalis* and *A. elongatum*. On the other hand, the study describes the elementary properties of the species, their conscious consumption as well as their possible positive or negative effects on health.

MATERIAL AND METHODS

Sample collection and preparation

Plant materials were harvested in fresh, edible form during the first two weeks of growth. The species are available in edible form for about 3 weeks in the wild. *A. orientale* was harvested on April 30, 2020, in the village of Balveren, Şırnak (altitude 1342 m, coordinates: 37° 29′ 30″ N and 42° 32′ 57″ E). *E. spectabilis* was harvested on May 10, 2020, to the west of Mount Namaz (altitude 1760 m, coordinates: 37° 32′ 19″ N and 42° 29′ 30″ E). *A. officinalis* was harvested on March 29, 2020, and *A. elongatum* on March 24, 2020, from Şırnak-Cizre road (Kumçatı) (altitude 522 m, coordinates: 37° 27′ 57″ N and 42° 17′ 17″ E). The plants were taken to the Laboratory of Biology and Chemistry of Şırnak University and photographed with a high-resolution camera (Nikon Coolpix P900 camera and 83×Zoom-NIKKOR ED Glass Lens). The plants were marked and identified by the plant physiology and taxonomy experts of the biology department of Dicle University and according to the Flora of Turkiye and Plant Databases. Preserved specimens were labelled according to herbarium techniques. After the identification, some of the species were dried and some were cleaned and stored in a deep freezer at -20 °C in poly-ethylene bags. Edible tissues (leaves) of the species were studied totally. Detailed information on the species, such as family and species names, Turkish and local names, traditional treatment and nutritional uses are given in Table 1.

Experimental devices, materials and chemicals

The analysis was done by the method of determination of trace elements (As, Cd, Hg, Pb) and other elements by inductively coupled plasma-mass spectrometry (ICP-MS: AGILENT/7800), after pressure digestion including the microwave heating technique. ICP-MS is an analytical technique device that can be used to measure elements at trace levels in organic foods. The device is used to determine 23 elements such as P, Na, Mg, K, Ca, Zn, Sn, Mn, Li, Fe, Cu, Cr, Co, B, Al, Sr, Se, Sb, Ni, Hg, As, Cd and Pb. Microwave, Teflon tube, plastic flask, 0.45 µm membrane filter, a vacuum manifold, syringe, plastic spatula, ceramic knife, automatic pipettes and scalpel were used as materials. Ultrapure water, nitric acid (65%, Suprapur), standard solutions of (1000 mg/L) of the elements, tune solution, argon (99.99% purity) and Helium (99.99% purity) were used as chemicals.

Processing of samples, standard solutions and concentration analysis

First, 15.4 mL of HNO_3 (Nitric acid-2%) and 6.75 mL of HCl (Hydrochloric acid-0.5%) were taken and transferred into a 500 mL volumetric flask. Then the flask was filled to 500 mL with ultra-pure water. For 500 ppb internal standard solutions, a 12.5 mL internal standard was taken. It was filled to the volume line with solutions of HNO_3 (2%) and HCl (0.5%) at 250 mL. The edible part (leaves) (0.5 g ± 1 mg) of the species was placed in Teflon tubes and the sample was accurately weighed. Ten mL of HNO_3 (65%) solution was added. The tightly closed Teflon tubes were placed in a microwave as indicated in the program and the burning process was started. After the combustion process was completed, the tubes were allowed to cool down to room temperature in the Fume Hood. The obtained solutions were checked to be transparent and completely burned. Then the solution was transferred to the appropriate volume of a plastic flask according to the dilution factor to be applied and completed with ultrapure water to the sample and increasing to the total volume to 100 mL. Then it was injected into the

Table 1. General characteristics of *A. orientale, E. spectabilis, A. officinalis* and *A. elongatum* and their therapeutic and nutritional usages.

Family Species	Turkish name Local name	Studied part (edible part)	Therapeutic and nutritional usages
(Alliaceae) *Allium orientale* Boiss.	Doğu soğanı, Soryaz	Young leaves	The bulbs and leaves are eaten raw or cooked. Flowers and leaves are used as a garnish in salads. Particularly the leaves are added to cheese and several traditional dishes. The therapeutic effects are antimicrobial, antioxidant, anticancer and antiseptic. The plant increases robustness, reduces cholesterol, reduces arteriosclerosis, is used as a tonic for the digestive system and strengthens the circulatory system (Karahan et al., 2020; Kardaș, 2019).
(Liliaceae) *Eremurus spectabilis* M. Bieb.	Çiriș otu, Gulik	Young leaves	It is used in many traditional dishes, especially in the omelet. It is consumed for vitamin C, B and antioxidant requirements. The therapeutic effects are antifungal and antimicrobial. It is used for the treatment of hemorrhoids, diabetes, peptic ulcer, skin diseases (eczema, boils, acne), burns, kidney diseases, ringworm, stomach ulcer, prostate and breast cancer, and as a milk and blood enhancer (Karahan et al., 2020; Kardaș, 2019).
(Boraginaceae) *Anchusa officinalis* L.	Sığırdili, Guriz	Young leaves	It is used in several traditional dishes and soups. It is used for the treatment of colds, flu, cough, depression, fear, stress, bronchitis, and as a diuretic and diaphoretic. It reduces the symptoms of rheumatism and stomach aches. It is used for healing open wounds in the intestines, stomach and duodenal ulcers. After boiling, it is wrapped in a cloth and left on the forehead of epilepsy patients for calming and relaxation. It is used as a sedative and antipyretic and also as an antidepressant, and for headache, dizziness and tinnitus (Karahan et al., 2020; Kardaș, 2019).
(Araceae) *Arum elongatum* Steven	Yılanyastığı, Kari	Young Leaves	It is cooked as a vegetable in dishes such as soup, stew, and omelets. It is mixed with mulberry molasses and applied to female breasts for healing wounds and reducing swelling. It is used as an anti-parasitic for the intestines. Its leaf and fruit are used for hemorrhoids, bladder diseases, and as an antidote to snake and scorpion poison. Drinking its boiled juice contributes to body regeneration, breastfeeding and relieves postpartum pain. It increases body resistance. It is eaten for menstruation, menopause and bleeding. It is added to the dowry of newly married brides as a gift to prevent gynecological diseases in southern Anatolia (Karahan et al., 2020; Kardaș, 2019).

ICP-MS. The results were obtained in µg/kg according to the value corresponding to the calibration curve obtained in the device. The device provides an automatic calculation of the element amount in the sample by entering the sample amount and the total volume. Measurement result (mg/kg) = (Device result × Completion volume) / Sample Quantity /1000. Each measurement was performed in triplicate and the results were averaged. Data, including the elemental properties of the species, were represented as the arithmetic mean, ranges and standard deviation values of three replicates of each sample.

RESULT AND DISCUSSION

A. orientale, E. spectabilis, A. officinalis and *A. elongatum* species are significant therapeutic and nutritious plants that are thought to have many positive effects on human health (Table 1) (Kardaş, 2019). Apart from minerals and heavy metals, other possible benefits of these species to human health have been described in many studies (Jakovljević, Vasić, Stanković, Topuzović, & Čomić, 2016; Jaradat & Abualhasan, 2016; Tosun et al., 2012); however, there are no detailed studies about their mineral and heavy metals accumulations. Although mostly the positive aspects of the species are investigated, they can also cause irreversible damages due to their toxic heavy metals levels. Therefore, examining these therapeutic plants from all aspects will help to reach a clear conclusion.

Macro-elements analysis of *A. orientale, E. spectabilis, A. officinalis* and *A. elongatum* showed that; P (462.856 mg/kg), Mg (731.012 mg/kg), K (4743.113 mg/kg), Ca (906.746 mg/kg) and Fe (1022.068 mg/kg) were major elements in *A. orientale*. P (472.188 mg/kg), Mg (260.743 mg/kg), K (3689.566 mg/kg) and Ca (732.388 mg/kg) were major elements in *E. spectabilis*. P (475.193 mg/kg), Mg (387.009 mg/kg), K (7496.435 mg/kg), Ca (2947.378 mg/kg) and Fe (268.862 mg/kg) were the main elements in *A. officinalis*. P (363.409 mg/kg), Mg (393.178 mg/kg), K (4069.964 mg/kg), Ca (1191.365 mg/kg) and Fe (699.932 mg/kg) were major elements in *A. elongatum* (Table 2). Acceptable and normal limits of some beneficial minerals in plants ranged as follows: 1000-50,000 mg/kg for K, 3000-30,000 mg/kg for Ca, 100-1000 mg/kg for Mg, 50-250 mg/kg for Fe (Kabata-Pendias & Pendias, 2001; Ozyigit et al., 2018), 360-470 mg/kg for P (on average in *E. spectabilis*) (Tosun et al., 2012). In general, the concentrations of the basic minerals P, K, and Mg in the current study were found within the acceptable and normal limits of edible plants. Only the Ca level was below the required values; however, just in *A. officinalis* was the Ca level very close to the sufficient level. Also, in the study on *E. spectabilis* (collected from Erzurum, Turkiye) the average concentration of P, K, Ca and Mg were found to be 430, 4040, 309 and 390 mg/kg, respectively (Tosun et al., 2012). The concentrations of P, K, Ca and Mg in *E. spectabilis* in the present study were 472.188, 3689.566, 732.388 and 260.743 mg/kg, respectively. The concentrations of the P, K, and Mg appear to be roughly close to the mentioned study (Tosun et al., 2012). This indicates that the plant generally accumulates essential elements at genetically similar proportions. However, the Ca level of the current study seems to be almost twice of the previous study (Tosun et al., 2012). This high amount may be related to the chemical composition of the soil or the collection season. Ca is the most abundant essential mineral with many functions such as the repair and construction of bones and teeth, the functioning of muscles and nerve tissues, the functioning and coordination of the brain and nervous system, blood circulation, and the hormonal system (Karahan et al., 2020; Soetan, Olaiya, & Oyewole, 2010). On the other hand, Fe concentrations in *A. orientale* and *A. elongatum* were found higher than the normal limit of an average plant (Table 3). However, the Fe concentra-

Table 2. The average concentration of minerals and heavy metals in the edible tissues (leaves) of *A. orientale, E. spectabilis, A. officinalis* and *A. elongatum* (mg/kg).

	Plant species			
Mineral and heavy metal	***A. orientale* (Mean*±SD)**	***E. spectabilis* (Mean*±SD)**	***A. officinalis* (Mean*±SD)**	***A. elongatum* (Mean*±SD)**
Phosphor (P)	462.856±48.554	472.188±49.533	475.193±49.848	363.409±38.122
Sodium (Na)	21.975±2.373	4.206±0.454	12.586±1.359	30.379±3.281
Magnesium (Mg)	731.012±71.201	260.743±25.396	387.009±37.695	393.178±38.296
Potassium (K)	4743.113±490.438	3689.566±381.501	7496.435±775.131	4069.964±420.834
Calcium (Ca)	906.746±95.571	732.388±77.194	2947.378±310.654	1191.365±125.570
Zinc (Zn)	7.839±0.810	6.809±0.703	21.757±2.248	9.906±1.023
Tin (Sn)	nd	nd	nd	nd
Manganese (Mn)	26.004±2.234	4.886±0.420	8.552±0.735	14.659±1.259
Lithium (Li)	0.794±0.067	nd	nd	nd
Iron (Fe)	1022.068±89.431	49.720±4.351	268.862±23.525	699.932±61.244
Copper (Cu)	2.252±0.184	1.379±0.113	2.518±0.206	2.066±0.169
Chromium (Cr)	3.433±0.272	nd	1.405±0.111	1.645±0.130
Cobalt (Co)	0.660±0.055	nd	nd	0.384±0.032
Boron (B)	2.741±0.224	2.344±0.191	2.410±0.197	1.980±0.162
Aluminum (Al)	889.368±78.443	33.489±2.954	150.737±13.295	651.570±57.468
Strontium (Sr)	2.308±0.306	1.533±0.203	8.001±1.059	2.831±0.375
Selenium (Se)	0.116±0.019	nd	0.175±0.029	0.085±0.014
Antimony (Sb)	nd	nd	0.010±0.001	nd
Nickel (Ni)	3.851±0.402	0.279±0.029	2.492±0.260	2.290±0.239
Mercury (Hg)	nd	nd	nd	nd
Arsenic (As)	0.124±0.012	0.008±0.001	0.073±0.007	0.087±0.008
Cadmium (Cd)	nd	nd	0.064±0.005	0.013±0.001
Lead (Pb)	0.183±0.016	0.047±0.001	0.202±0.018	0.156±0.014

Results expressed as a concentration (mg/kg) of mineral and heavy metals in the edible plant leaves.
*Mineral and heavy metal concentrations of the plants are an average of three replicates; Means ± SD (standard deviation), nd: not detected. Some minerals were not detected in the study due to the limited detectable range of the instrument and methods.

tion of *E. spectabilis* was lower than expected. The examined plants may not be rich in Ca, but rich in Fe, therefore *A. orientale* and *A. elongatum* might be recommended to be consumed as Fe sources. As known, Fe is a vitally essential element and due to its ability to exchange electrons, it is of great importance in ATP, DNA, RNA and protein synthesis and in the transport of oxygen by participating in the structure of hemoglobin as well as being necessary for the production and functioning of many enzymes and biomolecules (Roy & Enns, 2000; Soetan et al., 2010). Its deficiency adversely affects reproductive functions, growth and cognitive development and sometimes severe deficiency even causes anemia, mental disorders in children and causes premature births and infant weight loss in early pregnancy (Karahan et al., 2020; Soetan et al., 2010). It is worth noting that, *A. orientale* and *A. elongatum*, which are rich in Fe, are consumed as milk enhancers and strengthening agents for postpartum women in most of the rural part of Anatolia. Besides, *A. orientale* and *A. elongatum* consumed for therapeutic purposes during the menstrual period and postpartum has been considered to be involved in the synthesis of hemoglobin and compensate for blood loss. Additionally, Mg and K have many high-quality outcomes on human health (Karahan et al., 2020; Long & Romani, 2015; Soetan et al., 2010).

The heavy metal accumulation of a plant can be influenced by many factors such as the physiology of the plant, the structure of the soil, the pH of the soil, the chemical environment of the soil, the presence of mines, factories or facilities close to the growing region, the concentration of heavy metals in polluted air and irrigation water, etc. In the present study Mn concentration was determined as 26.004, 4.886, 8.552 and 14.659 mg/kg in *A. orientale, E. spectabilis, A. officinalis* and *A. elongatum*, respectively (Table 2). The level of Mn was below the sufficient concentration of 30-300 mg/kg in an average plant leaf (Table 3). Only the Mn level in *A. orientale* was close to the adequate limit. Mn is vital for glucose metabolism, bone structure, immune and neural functions, activation of many enzymes, the functions in cartilage and connective tissue, lipid and cholesterol metabolism, and antioxidants for free radicals, formation of amino acids and coenzyme activity (Karahan et al., 2020; Santos, Batoreu, Mateus, Marreilha dos Santos, & Aschner, 2014; Soetan et al., 2010).

Zn was detected at the level of 7.839, 6.809, 21.757 and 9.906 mg/kg in *A. orientale, E. spectabilis, A. officinalis* and *A. elongatum,* respectively (Table 2). The amounts did not exceed the sufficient concentration of 27-150 mg/kg in an average plant leaf (Table 3). Zn level in *A. officinalis* was 21.757 mg/kg and the concentration of Zn was quite above the EPA maximum contamination level (5 mg/L) (Table 4). However, it was near the sufficient level of the general plants limit (Table 3). It has been emphasized that the Zn level is higher than the sufficient concentration of a leaf 27-150 mg/kg in many studies. In a study on Zn, *Polygonum hydropiper* L. growing on contaminated soils in a sewage pond had accumulated 1061 mg/kg of Zn in its shoots and *Rumex acetosa* L. growing near a smelter accumulated more than 900 mg/kg of Zn both in its shoots and roots (Wang, Cui, Liu, Dong, & Christie, 2003). In addition, although Zn is an essential element, its high accumulation in the body causes dizziness and fatigue (Table 4) (Dixit et al., 2015). The Cu level of the current study ranged from 1.379 to 2.518 mg/kg (Table 2). According to the EPA maximum contamination limit of drinking water, Cu should be 1.3 mg/L, and according to the sufficient limit of a plant leaf, it should be between 5-30 mg/kg. The Cu concentration was determined as 2.252, 1.379, 2.518 and 2.066 mg/kg in *A. orientale, E. spectabilis, A. officinalis* and *A. elongatum*, respectively (Table 2). The quantities of Cu did not exceed the sufficient concentration of an average plant leaf (Table 3). As is known, high levels of Cu cause discomfort such as brain and kidney damage, liver cirrhosis and chronic anemia, and stomach and intestine irritation (Dixit et al., 2015; Nik Abdul Ghani et al., 2021).

Al concentration was determined as 889.368, 33.489, 150.737 and 651.570 mg/kg in *A. orientale, E. spectabilis, A. officinalis* and *A. elongatum*, respectively. Al concentration in soil is between 10,000 and 300,000 mg/kg (Neenu & Karthika, 2019). Al is not considered an essential nutrient for plants, but small concentrations can sometimes increase plant growth or bring other desired effects (Neenu & Karthika, 2019). There is no clear value regarding the limit of Al in medicinal plants. For example, Al could not be detected in some medicinal plants (Bhat et al., 2010), but moderate concentrations (30.983-368.877 mg/kg) were mentioned in another study (Karahan et al., 2020). Al concentration was high in *A. orientale* 889.368 mg/kg and *A. elongatum* (651.570 mg/kg). These high concentrations indicate that consuming *A. orientale* and *A. elongatum* may lead to drawbacks (Malluche, 2002; Molloy et al., 2007).

In the study of medicinal plants *Euphorbia hirta, Peristrophe bycaliculata, Tinospora cordifolia*, *Abutilon indicum* and *Calotropis procera*, it was observed that the heavy metal levels (particularly Pb, Cd, Cr and Ni) are different in the same medicinal plant collected from different parts of the same city (Barthwal, Nair, & Kakkar, 2008). In another study on onion (*Allium*) tuber and leaf, the level of Cr in the tuber and Fe in the leaf were found at high levels of 2.3 mg/kg and 425.5 mg/kg, respectively (Bedassa et al., 2017). The mineral and heavy metal contents of wild plants in the Kohistan region (Pakistan) were investigated. The concentration of Na, K, Ca, Mg, Fe, Mn, Cr, Ni, Co, Cu, Pb, Zn and Cd were as follows; 19 to 225 mg/kg, 2515 to 12595 mg/kg, 1602 to 24687 mg/kg, 898 to 5487 mg/kg, 187 to 5054 mg/kg, 22 to 857 mg/kg, 6 to 27 mg/kg, 10 to 44 mg/kg, 1 to 15 mg/kg, 4 to 66 mg/kg, 8 to 31 mg/kg, 7 to 328 mg/kg and 0.2 to 2.1 mg/kg, respectively (Muhammad et al., 2011). It was reported that most of the elements were not at a detrimental level. In a report on 17 medicinal plants from different parts of Turkiye, the measured element levels were (in mg/kg) 30.983 - 368.877 for Al, 13.845 - 186.015 for B, 1335.699 - 11213.951 for Ca, 0.016 - 0.653 for Cd, 0.379 - 30.708 for Cr, 23.838 - 90.444 for Cu, 78.960 - 1228.845 for Fe, 1035.948 - 6393.491 for K, 83.193 - 2252.031 for Mg, 12.111 - 362.570 for Mn, 278.464 - 1968.775 for Na, 1.945 - 35.732 for Ni, 0.796 - 17.162 for Pb and 166.910 - 395.252 for Zn (Karahan et al., 2020). In the study, *Vitiveria zizinalis* had the highest concentration of toxic heavy metals, including As (5.31 mg/kg), Cr (0.674 mg/kg), Co (1.02 mg/kg), Hg (0.36 mg/kg), and Ni (0.328 mg/kg), conversely, Al, Ba, Cd, and Mo heavy metals were not detected (Bhat et al., 2010).

Table 3. Average concentrations of trace and heavy elements (mg/kg) in a mature leaf tissue for various plant species. The table is adapted from the literature (Kabata-Pendias & Pendias, 2001).

Trace and heavy Elements	Excessive (toxic) concentration	Sufficient (normal) concentration	Trace and heavy Elements	Excessive (toxic) concentration	Sufficient (normal) concentration
Ag	5-10	0.5	Mn	400-1000	30-300
As	5-20	1-1.7	Mo	10-50	0.2-5
B	50-200	10-100	Ni	10-100	0.1-5
Ba	500	-	Pb	30-300	5-10
Be	10-50	1-7	Se	5-30	0.01-2
Cd	5-30	0.05-0.2	Sn	60	-
Co	15-50	0.02-1	Sb	150	7-50
Cr	5-30	0.1-0.5	Ti	50-200	-
Cu	20-100	5-30	Tl	20	-
F	50-500	5-30	V	5-10	0.2-1.5
Hg	1-3	-	Zn	100-400	27-150
Li	5-50	3	Zr	15	-

Values are not given for very sensitive or highly tolerant plant species. Values are given in mg/kg.

Table 4. Maximum contaminant level of toxic heavy metals for drinking water and potential health effects from long-term exposure above the maximum contaminant level (EPA, Environmental Protection Agency). The table is adapted from the literature (Apori, Atiah, Hanyabui, & Byalebeka, 2020; Dixit et al., 2015; Nik Abdul Ghani, Jami, & Alam, 2021).

Toxic heavy metals	Potential effects on human health for long-term exposure	EPA maximum contamination limit (mg/L)
As	Adversely affects the basic cellular processes oxidative phosphorylation and ATP synthesis	0.01
Cd	Mutagenic, endocrine disruptor, carcinogenic, lung damage, fragile bones, affects calcium regulation in body systems	0.005
Cr	Hair loss, skin irritation, skin sensitization, allergy	0.1
Cu	High levels cause liver cirrhosis and chronic anemia, stomach and intestine irritation, brain and kidney damage	1.3
Hg	Autoimmune diseases, fatigue, drowsiness, hair loss, depression, insomnia, amnesia, restlessness, defect of vision, temper outbursts, brain damage, tremors, lung and kidney failure	0.002
Pb	Overexposure in children and babies causes developmental impairment, decreased intelligence, short-term memory loss, learning and coordination problems, and cardiovascular disease risk	0.015
Se	Dietary exposure of approximately 300 µg per day affects endocrine function, impairment of natural killer cell activity, gastrointestinal disturbances and hepatotoxicity	0.050
Zn	Excessive exposure causes fatigue, dizziness, nausea, vomiting, diarrhea, metal taste, and kidney and stomach damage	5

Maximum contaminant level of toxic heavy metals is prepared according to *Drinking Water Contaminants;* United States Environmental Protection Agency (EPA): Washington, DC, USA, 2009.

On the other hand, some wild herbal plants contain very high amounts of specific heavy metals. As known, *Hypericum perforatum* L. is one of the most important medicinal plants used as an anti-depressive agent (Kim, Streltzer, & Goebert, 1999; Verotta, 2003). Recent studies have shown that *H. perforatum* can accumulate higher concentrations of Cd than other plants grown under the same conditions (Chizzola & Lukas, 2006; Masarovičová, Katarina, Kummerová, & Kmentova, 2004). The species of the present study do not show consistent results when compared with the above studies. Undoubtedly, heavy metal accumulation in a plant is mainly due to internal and external factors. Notably, the harvesting area of *A. orientale,* *E. spectabilis, A. officinalis* and *A. elongatum* are mountainous lands far from industrial areas and settlements. The location of the species strengthens the fact that the heavy metal accumulation capacity of the examined species is due to internal factors. Considering all these results, although each species has its heavy metal and macro-element accumulation feature, the chemical structure of the soil and environmental heavy metal contamination can also change the elemental profile of a plant (Sarma, Deka, Deka, & Saikia, 2012).

Li was found at the level of 0.794 mg/kg in *A. orientale*, and Sb was found at the level of 0.010 mg/kg in *A. officinalis*. The excessive concentration of Li for leaf tissue is 5 mg/kg and for Sb, the excessive concentration is 150 mg/kg. Exceeding the concentration limit poses a danger to the body (Table 3). Cr concentration was determined as 3.433 mg/kg in *A. orientale*, 1.404 mg/kg in *A. officinalis* and 1.645 mg/kg in *A. elongatum* (Table 2). These levels were high when compared to both the EPA limit (0.1 mg/L) (Table 4) and an average plant leaf limit (0.1-0.5 mg/kg) (Table 3). Nevertheless, the results of the current study did not exceed the toxic level of an average plant tissue. On the other hand, the amounts of Ni in *A. orientale, E. spectabilis, A. officinalis* and *A. elongatum* were determined as 3.851, 0.279, 2.492 and 2.290 mg/kg, respectively (Table 2). Ni levels do not exceed the danger limit accepted in Table 3. The concentration of Pb varied between 0.047 and 0.202 mg/kg. The concentration of Pb in plant leaves is between 5 and10 mg/kg (Table 3). The highly toxic As ranged from 0.008 to 0.124 mg/kg in the studied species. Cd, another dangerous heavy metal, was not found in *A. orientale* or *E. spectabilis*, however, it was detected at levels of 0.064 and 0.013 mg/kg in *A. officinalis* and *A. elongatum*, respectively. Concentrations of toxic heavy metals Co, B and Se in *A. orientale, E. spectabilis, A. officinalis* and *A. elongatum* plants did not exceed the limit applicable for an average plant tissue (Table 3).

CONCLUSION

As a result, the concentration of the elements and heavy metals, with the exception of Cr and Al, in the plants, were within acceptable limits. However, the high concentration of Al in *A. orientale* and *A. elongatum* indicated that these plants should be consumed carefully. On the other hand, the fact that high levels of Fe in *A. orientale* and high levels of K and Ca in *A. officinalis* show that these plants can be consumed as nutrients in the supply of essential elements for the body. Moreover, the traditional postnatal use of *A. orientale* and *A. elongatum* is probably related to the presence and high concentration of Fe, a precursor in blood synthesis. The concentrations of toxic metals such as As, Cd, Pb, Ni, Sn, Co, Se, Sb, Hg and Cu were determined far from the danger limits. Finally, as the studied plants are frequently sold as vegetables in public markets, any study on the nutritional analysis of these plants will benefit the consumer sector.

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