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Exploring the health impacts of mineral and heavy metal concentrations in wild plants with nutritional and medicinal value

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ABSTRACT

The research set out to quantify mineral and heavy metal concentrations in four wild plants: Allium orientale Boiss., Eremurus spectabilis M. Bieb., Anchusa officinalis L., and Arum elongatum Steven. These species are both nutritionally and medicinally valuable. Procedures: Inductively coupled plasma mass spectrometry (ICP-MS) was used to examine the presence and amount of 23 heavy metals and minerals.

End result: Calcium, magnesium, iron, and aluminum were the most prevalent minerals. Elements Ni, Cu, Mn, B, and Na were somewhat plentiful. Low or nonexistent quantities of toxic heavy metals like Sn, Li, Co, Se, Sb, Hg, Cd, As, and Pb were found. Both potassium (7496.435 mg/kg) and calcium (2947.378 mg/kg) were found in abundance in A. officinalis. In contrast, A. orientale and A. elongatum had quite high iron contents (1022.068 and 699.932 mg/kg, respectively). Compared to the other three plants, A. orientalale had almost double the content of magnesium (731.012 mg/kg). At 889.368 mg/kg and 651.570 mg/kg, respectively, Al was present in A. orientale and A. elongatum. Plants A. orientale, A. officinalis, and A. elongatum had Cr contents that were higher than the EPA standards and the industry norm.

The research concludes that four common wild plants utilized in alternative medicine and nutrition have different elemental profiles, heavy metal contents, and potential impacts on human health. There isn't a lot of pollution from most of the elements. Nutritional and comparative studies may also benefit from the findings, and the food and pharmaceutical businesses can find them valuable.

Mineral, medicinal plant, edible wild plant, heavy metal, nutrition

INTRODUCTION

Minerals are nutritional building blocks that play an essential role in maintaining a steady internal fluid balance, proper nerve and muscle function, proper homeostasis, enzyme and hormone activity, bone and tooth development, muscle and muscle repair, blood clotting, and many other bodily processes. Most minerals have critical roles in enzyme systems and metabolic activities, and even at threshold levels, they contribute considerably to proper development (Bhat, Kiran, Arun, & Karim, 2010). Although plants are selective in the elements they take up from the soil, heavy metals are more readily taken up by plant tissues as the soil's critical element levels rise, and these metals end up indirectly in the food chain. Some plants and processes need the elements Co, Al, Na, Si, Ni, and V, while others are important for general plant growth (C, H, O, N, P, K, S, Ca, Mg, Fe, Zn, Mn, Cu, B, Cl, and Mo) (Okcu, Tozlu, Kumlay, & Pehluvan, 2009).

The most famous heavy metals are mercury, lead, iron, copper, nickel, zinc, cadmium, arsenate, chromium, lead, silver, selenium, and thallium, however there are more than sixty such elements. But there are a few heavy metals that the body really needs, and these are Fe, Mn, Cu, Ni, and Zn.

This is why their physiological effects are proportional to the amounts found in the plant's edible portions. According to Okcu et al. (2009), although depleting these vital components might lead to noticeable bodily symptoms, building up excessive quantities can be harmful. The most harmful heavy metals for humans are barium, silver, copper, chromium, nickel, mercury, lead, cadmium, selenium, and arsenate. According to Jaishankar, Tseten, Anbalagan, Mathew, and Beeregowda (2014), the primary causes of their harmful effects on humans stem from problems with intracellular metabolic processes. These include DNA, RNA, ATP, organelle and cell membrane damage, biomolecular degradation, enzyme inactivation, mitochondrial damage, apoptosis, organ failure, autoimmune diseases, and neurological disorders.

Recent years have seen an uptick in study on wild edible plants' nutritional worth, culinary applications, and gastronomy tourism, in addition to the traditional medical and ethnobotanical uses of these plants. It is beneficial for human health to be aware of the advantages and disadvantages of wild plants by learning about their nutritional and medicinal qualities. The mineral and heavy metal content of nutritional and medicinal plants has been the subject of extensive research in recent years (Aberoumand & Deokule, 2009; Bedassa, Abebaw, & Desalegn, 2017; Bhat et al., 2010; Ceylan & Alıc, 2015; Maharia, Dutta, Acharya, & Reddy, 2010; Muhammad, Shah, & Khan, 2011). Hemorrhoids, diabetes, peptic ulcers, skin disorders, burns, renal illnesses, ringworm, gastrointestinal system diseases, colds, flu, cough, depression, anxiety, stress, neurological dysfunction, and bronchitis are just a few of the many conditions that have traditionally been treated using herbal remedies derived from wild plants.

Important benefits such as reducing kidney stones, increasing milk production, eliminating menstruation, decreasing cholesterol, and providing pain relief are also believed to be associated with them. The research material consists of four edible wild plants, the ranges of which are as follows. The Eastern onion, scientifically known as Allium orientale, is a member of the Alliaceae family that originated in the Eastern Mediterranean, Egypt, Levant, Libya, Cyprus, Sinai, and Turkiye. The Foxtail Lilly, or Eremurus spectabilis, is a member of the Liliaceae family that is indigenous to a number of countries, including Iran, Iraq, Turkey, Syria, the North Caucasus, Palestine, southern Russia, Transcaucasia, and Turkmenistan. Native to the area between the Caucasus and Europe, Anchusa officinalis (Alkanet) is a member of the Boraginaceae family. According to Karahan et al. (2020) and Kardaş (2019), the Arum elongatum, also known as the cuckoo pint, is a member of the Araceae family and may be found in some regions of Turkey, Bulgaria, Ukraine, Greece, Palestine, Crimea, southern Russia, the North Caucasus, and Transcaucasia. The primary goal of this research is to quantify the mineral and heavy metal content of the medicinal and edible wild plants A. orientale, E. spectabilis, A. officinalis, and A. elongatum. Conversely, the research details the species' basic characteristics, how they are consumed consciously, and any potential health benefits or drawbacks.

MATERIAL AND METHODS

Preparation and gathering of samples

There was a two-week window of opportunity to collect the plant components while they were still fresh and delicious. In the wild, you may find this species in an edible condition for around three weeks. On April 30, 2020, at a height of 1342 m and with coordinates 37° 29' 30" N and 42° 32' 57" E, in the hamlet of Balveren, Şırnak, A. orientale was collected. The harvest of E. spectabilis took place on May 10, 2020, at a height of 1760 m, in the vicinity of Mount Namaz (37° 32' 19" N and 42° 29' 30" E). The Şırnak-Cizre road (Kumçatı) (height 522 m, coordinates: 37° 27’ 57" N and 42° 17’ 17" E) was the site of the March 29, 2020, and March 24, 2020, harvests of A. officinalis and A. elongatum, respectively. A Nikon Coolpix P900 camera with an 83×Zoom-NIKKOR ED glass lens was used to capture high-resolution photographs of the plants at Şırnak University's Laboratory of Biology and Chemistry. In accordance with the Flora of Turkiye and Plant Databases, as well as the expertise of the biology department at Dicle University in plant physiology and taxonomy, the plants were tagged and identified. Herbarium procedures were followed while labeling preserved specimens. Once the species had been identified, they were either dried or cleaned before being placed in poly-ethylene bags and placed in a deep freezer set at -20 °C. The whole study focused on the species' edible tissues, namely their leaves. Species details, including Turkish and local names, traditional applications, nutritional value, and family and species names, are provided in Table 1.

Tools, supplies, and substances for experimentation

Inductively coupled plasma mass spectrometry (ICP-MS: AGILENT/7800) was used to determine trace elements (As, Cd, Hg, Pb, and others) after pressure digestion that included the microwave heating approach. ICP-MS is a tool for analytical techniques that can detect components in organic foods at tiny amounts. Here are 23 elements that may be found with the device: P, Na, Mg, K, Ca, Zn, Sn, Mn, Li, Fe, Cu, Cr, Co, B, Al, Sr, Se, Sb, Ni, Hg, As, Cd, and Pb. A vacuum manifold, syringe, plastic spatula, ceramic knife, automated pipettes, a microwave, a Teflon tube, a plastic flask, a 0.45 µm membrane filter, a vacuum, and a scalpel were all used as tools. Ingredients utilized as chemicals included 65% Suprapur nitric acid, tune solution, argon (99.99% purity), helium (99.99% purity), and standard elements solutions (1000 mg/L).

Analyzing concentrations, processing samples, and using standard solutions

We started by filling a 500 mL volumetric flask with 15.4 mL of HNO3 (Nitric acid-2%) and 6.75 mL of HCl (Hydrochloric acid-0.5%). The next step was to add 500 mL of ultra-pure water to the flask. The internal standard solution with a concentration of 500 ppb required 12.5 mL. Using 250 mL of liquids containing 2% HNO3 and 0.5% HCI, it was filled up to the volume line. The leaves, which are edible, were measured in grams with a standard deviation of one milligram and then transferred to Teflon tubes for precise weighing. A ten milliliter solution of HNO3 (65%) was then added. Following the program's instructions, the Teflon tubes were put in a microwave to begin the burning process. The tubes were let to cool down to room temperature in the Fume Hood once the combustion process was finished. The resulting solutions were examined to ensure they were clear and fully oxidized. Next, the solution was carefully transferred to a plastic flask of the correct capacity based on the dilution factor that would be used. The sample was then filled up to a total volume of 100 mL by adding ultrapure water. What followed was its injection 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; Kardaş, 2019).
(Liliaceae) *Eremurus spectabilis* M. Bieb.	Çiriş 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; Kardaş, 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; Kardaş, 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; Kardaş, 2019).

ICP-MS. The values matching to the calibration curve produced in the device were used to derive the results, which were expressed in µg/kg. Once you input the sample quantity and total volume, the gadget will automatically calculate the number of elements in the sample. The dosage per kilogram is calculated by dividing the device result by the completion volume, then dividing the sample quantity by 1000. We averaged the data after doing each measurement three times. Mathematical means, ranges, and standard deviations of three independent samples were used to describe data, which included the species' elemental characteristics.

RESULT AND DISCUSSION

According to Kardası (2019), there are several beneficial impacts on human health associated with the nutritional and medicinal properties of the A. orientale, E. spectabilis, A. officinalis, and A. elongatum species of plants. Although numerous studies have discussed potential advantages of these species to human health beyond minerals and heavy metals (Jakovljević, Vasić, Stanković, Topuzović, & Čomić, 2016; Jaradat & Abualhasan, 2016; Tosun et al., 2012), no comprehensive research has examined the accumulation of these substances. While most studies focus on the species' beneficial traits, the high quantities of harmful heavy metals they contain may cause permanent harm. In order to get to the bottom of these medicinal plants, it's important to look at them from every angle.

A. orientale, E. spectabilis, A. officinalis, and A. elongatum were found to have the following macro-elements: P (462.856 mg/kg), Mg (731.012 mg/kg), K (4743.113 mg/kg), and Ca (906.746 mg/kg) according to the examination.

Major components found in A. orientale included and (1022.068 mg/kg).

The most abundant elements in E. spectabilis were potassium (3689.566 mg/kg), calcium (732.388 mg/kg), magnesium (260.743 mg/kg), and phosphorus (472.188 mg/kg). The primary elements found in A. officinalis were sodium (475.193 mg/kg), magnesium (387.009 mg/kg), potassium (7496.435 mg/kg), calcium (2947.378 mg/kg), and iron (268.862 mg/kg). Iron (699.932 mg/kg), magnesium (393.178 mg/kg), potassium (4069.964 mg/kg), calcium (1191.365 mg/kg), and phosphorus (363.409 mg/kg) were the main elements found in A. elongatum, according to Table 2. Some beneficial minerals have acceptable and normal limits in plants, such as potassium (1000–50,000 mg/kg), calcium (300–30,000 mg/kg), magnesium (100–1000 mg/kg), iron (50–250 mg/kg; Kabata–Pendias & Pendias, 2001; Ozyigit et al., 2018), and phosphorus (360–470 mg/kg; on average in E. spectabilis) (Tosun et al., 2012). All things considered, the present investigation discovered P, K, and Mg contents in edible plants that were within the acceptable and normal range. The Ca level was the only one that fell short of the necessary standards; nonetheless, it was in A. officinalis where the Ca level was really near to the adequate level. Tosun et al. (2012) also reported that the average content of P, K, Ca, and Mg in E. spectabilis, which was obtained from Erzurum, Turkiye, was 430, 4040, 309, and 390 mg/kg, respectively. In this investigation, E. spectabilis contained 472.188 mg/kg of P, 3689.566 mg/kg of K, 732.388 mg/kg of Ca, and 260.743 mg/kg of Mg. It would seem that the P, K, and Mg concentrations are rather near to the one found in the aforementioned research (Tosun et al., 2012). This suggests that plants often store important components in quantities that are determined by their genes. In contrast to the earlier research (Tosun et al., 2012), the present study seems to have a Ca level that is almost double. Maybe the chemical make-up of the soil or the time of year when the samples were taken is to blame for this astronomical sum. According to Karahan et al. (2020) and Soetan, Olaiya, and Oyewole (2010), calcium is the most abundant essential mineral and has numerous roles in the body, including building and repairing bones and teeth, facilitating the function of muscles and nerve tissues, regulating blood circulation, and assisting with the hormonal system. Table 3 shows that, in contrast, A. orientale and A. elongatum had Fe contents that were greater than the typical plant's normal limit. Yet, the concentration of iron

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.

less E. spectabilis than anticipated. Because of their high iron content, the plants under investigation—A. orientale and A. elongatum—may be suggested for use as dietary sources of iron rather than calcium. In addition to its role in the production and function of numerous enzymes and biomolecules, iron is known to play an essential role in the transport of oxygen through its involvement in the structure of hemoglobin and in the synthesis of ATP, DNA, RNA, and proteins (Roy & Enns, 2000; Soetan et al., 2010). Inadequate levels have negative effects on growth, cognition, and reproduction; in extreme cases, they may lead to anemia, childhood mental illnesses, preterm delivery, and low birth weight (Karahan et al., 2020; Soetan et al., 2010). In most rural parts of Anatolia, women take A. orientale and A. elongatum, two plants that are rich in iron, to strengthen themselves after giving birth and to increase the amount of milk they produce. A. orientale and A. elongatum, which are taken therapeutically throughout the menstrual cycle and after giving birth, are thought to have a role in hemoglobin production and to compensate for blood loss. Karahan et al. (2020), Long and Romani (2015), and Soetan et al. (2010) all note that magnesium and potassium have several positive effects on human health.

Several factors can affect the amount of heavy metals that plants absorb. These include the plant's physiology, the soil's structure and pH, the soil's chemical environment, the proximity of nearby mines, factories, or other industrial sites, the concentration of heavy metals in contaminated air and irrigation water, and many more. The current investigation found that A. orientale, E. spectabilis, A. officinalis, and A. elongatum all had concentrations of Mn of 26.004, 4.886, 8.552, and 14.659 mg/kg, respectively (Table 2). Table 3 shows that the average plant leaf had less than the recommended concentration of manganese, which is 30-300 mg/kg. Only A. orientale had a Mn level that was near the acceptable limit. According to Karahan et al. (2020), Santos, Batoreu, Mateus, Marreilha dos Santos, and Aschner (2014), and Soetan et al. (2010), manganese is essential for many metabolic processes, including glucose metabolism, bone formation, immune and neurological functions, enzyme activation, connective tissue and cartilage functions, lipid and cholesterol metabolism, and antioxidant defense against free radicals.

Zeta orientale, E. spectabilis, A. officinalis, and A. elongatum were found to have 7.839, 6.809, 21.757, and 9.906 mg/kg of Zn, respectively, according to Table 2. There was no concentration higher than 27–150 mg/kg in a typical plant leaf (Table 3). The zinc content in A. officinalis was 21.757 mg/kg, which is much higher than the maximum contamination threshold of 5 mg/L set by the EPA (Table 4). Nonetheless, it was close to the typical plants' adequate limit (Table 3). The Zn level exceeds the adequate concentration of a leaf (27-150 mg/kg), as shown in several studies. Research on zinc found that plants near smelters acquired over 900 mg/kg of zinc in their roots and shoots, whereas Polygonum hydropiper L. grown on polluted soils in a sewage pond accumulated 1061 mg/kg in its shoots (Wang, Cui, Liu, Dong, & Christie, 2003). Furthermore, zinc is an important element, but too much of it might make you feel lightheaded and exhausted (Table 4; Dixit et al., 2015). Copper concentrations in this investigation varied between 1.379% and 2.518% (Table 2). Copper levels in drinking water should not exceed 1.3 mg/L, according the EPA, while levels in plant leaves should not exceed 5-30 mg/kg, per the adequate limit.

In Table 2, we can see that the Cu concentration was 2.066 mg/kg for A. elongatum, 2.252 mg/kg for A. orientale, 1.379 mg/kg for E. spectabilis, and 2.518 mg/kg for A. officinalis. Table 3 shows that the amounts of Cu were below what would be considered an adequate concentration for an average plant leaf. Damage to the brain and kidneys, cirrhosis of the liver and chronic anemia, irritation of the intestines and stomach, and persistent pain are all symptoms of Cu poisoning, which is well-known to induce discomfort (Dixit et al., 2015; Nik Abdul Ghani et al., 2021).

The concentrations of aluminum in A. orientale, E. spectabilis, A. officinalis, and A. elongatum were found to be 889.368 mg/kg, 33.489 mg/kg, 150.737 mg/kg, and 651.570 mg/kg, respectively. The amount of aluminum in soil ranges from 10,000 to 300,000 mg/kg, according to Neenu and Karthika (2019). Even while alkalinity isn't strictly necessary for plant development, it may have some positive benefits when applied in trace amounts (Neenu & Karthika, 2019). When it comes to medicinal plants, there is no definitive figure for the limit of Al. For instance, one research found no Al in some medicinal herbs (Bhat et al., 2010), while another study found intermediate quantities (30.983-368.877 mg/kg) (Karahan et al., 2020). In terms of aluminum content, A. orientale had 889.368 mg/kg and A. elongatum 651.570 mg/kg. A. orientale and A. elongatum use may result in negative outcomes due to these high concentrations (Malluche, 2002; Molloy et al., 2007).

Heavy metal levels, especially lead, cadmium, nickel, and chromium, vary among medicinal plants collected from different locations within the same city, according to research on Euphorbia hirta, Peristrophe bycaliculata, Tinospora cordifolia, Abutilon indicum, and Calotropis procera (Barthwal, Nair, & Kakkar, 2008). The levels of Cr in the onion tuber were found to be 2.3 mg/kg and Fe in the leaf to be 425.5 mg/kg, respectively, in another research on onion (Allium) (Bedassa et al., 2017). Researchers in Pakistan's Kohistan area looked at the amounts of minerals and heavy metals in natural plants.

According to Muhammad et al. (2011), the following concentrations of Na, K, Ca, Mg, Fe, Mn, Cr, Ni, Co, Cu, Pb, Zn, and Cd were measured: 19–225 mg/kg, 2515–12595 mg/kg, 1602–24687 mg/kg, 898–5487 mg/kg, 187–5054 mg/kg, 22–857 mg/kg, 6–27 mg/kg, 10–44 mg/kg, 1–15 mg/kg, 4–66 mg/kg, 8–31 mg/kg, 7–328 mg/kg, and 0.2–2.1 mg/kg, respectively. Most of the components were deemed to not be at a harmful 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). The research found that harmful heavy metals were most concentrated in Vitiveria zizinalis, with concentrations of 5.31 mg/kg of As, 0.674 mg/kg of Cr, 1.02 mg/kg of Co, 0.36 mg/kg of Hg, and 0.328 mg/kg of Ni. In contrast, heavy metals such as Al, Ba, Cd, and Mo were not discovered (Bhat et al., 2010).

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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.

Conversely, the concentrations of some heavy metals in wild herbal plants might be rather high. Kim, Streltzer, and Goebert (1999) and Verotta (2003) both agree that Hypericum perforatum L. is a powerful antidepressant. Chizzola and Lukas (2006) and Masarovičová, Katarina, Kummerová, and Kmentova (2004) found that, when cultivated under same circumstances, H. perforatum may accumulate greater quantities of Cd than other plants. When comparing the species in this research to those in the previous studies, the findings are inconsistent. Factors both inside and outside of a facility might contribute to the buildup of heavy metals. Most notably, the A. orientale harvesting region, The hilly regions far from industrial centers and villages are home to E. spectabilis, A. officinalis, and A. elongatum. The analyzed species' heavy metal accumulation capability is likely attributable to internal causes, as supported by their location.

Taking into account all of these findings, it is important to note that although each species does have its own mechanism for the accumulation of macro- and heavy metals, the chemical composition of the soil and environmental pollution may also alter a plant's elemental profile (Sarma, Deka, Deka, & Saikia, 2012).

The Li concentration in A. orientale was 0.794 mg/kg, whereas the Sb concentration in A. officinalis was 0.010 mg/kg. At 5 mg/kg, Li is considered an excess concentration in leaf tissue, whereas at 150 mg/kg, Sb is considered an excessive concentration. According to Table 3, the body is put at risk when the concentration exceeds the limit. Table 2 shows that the concentrations of Cr in A. orientale, A. officinalis, and A. elongatum were 3.433 mg/kg, 1.404 mg/kg, and 1.645 mg/kg, respectively. In comparison to the EPA limit of 0.1 mg/L (Table 4) and the average limit of 0.1-0.5 mg/kg (Table 3), these values were elevated. In any case, the present study's findings were below the typical plant tissue's hazardous threshold. In contrast, Table 2 shows that A. orientale had 3.851 mg/kg of Ni, E. spectabilis 0.279 mg/kg, A. officinalis 2.492 mg/kg, and A. elongatum 2.290 mg/kg. The levels of Ni do not above the acceptable risk limit as shown in Table 3. From 0.047 to 0.202 mg/kg, the lead levels ranged.

Table 3 shows that the concentration of lead in plant leaves ranges from 5 to 10 mg/kg. In the species that were examined, the levels of very harmful As varied between 0.008 and 0.124 mg/kg. Cd, another harmful heavy metal, was not discovered in A. orientale or E. spectabilis, but it was in A. officinalis and A. elongatum, at concentrations of 0.064 and 0.013 mg/kg, respectively. The levels of harmful heavy metals Co, B, and Se in plants of A. orientale, E. spectabilis, A. officinalis, and A. elongatum were below the threshold that is considered acceptable for typical plant tissue (Table 3).

CONCLUSION

Consequently, the plants' elemental and heavy metal concentrations were within permissible ranges, with the exception of Cr and Al. It is important to use caution while consuming A. orientale and A. elongatum due to their high aluminum content. Conversely, the fact that A. officinalis has significant amounts of K and Ca and A. orientale contains high levels of Fe indicates that these plants may be ingested as nutrients to feed the body with important minerals. Because of its high concentrations of iron, a precursor in blood production, A. orientale and A. elongatum have traditionally been used after birth. Nearly all of the hazardous metal concentrations (As, Cd, Pb, Ni, Sn, Co, Se, Sb, Hg, and Cu) were found to be far below the threshold of risk. Lastly, public market vendors sometimes sell the plants under investigation as vegetables, so any research into their nutritional value will be useful to shoppers.

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