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CONTRADICTORY ASPECTS OF BIOACCUMULATION. ICP-MS, AN APPROACHABLE METHOD FOR ELEMENTAL CHARACTERIZATION OF CROP MEDICINAL PLANTS

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Metal bioaccumulation property is recognized and attributed to several plant species that are used for phytoremediation of contaminated soils. This feature cannot be ignored when the herb is a medicinal plant, even cultivated in nonpolluted area. This dual implication, beneficial for soil depollution, but critical in transmitting the accumulated metals to humans, must be considered. The surface elemental characterization by Scanning electron microscopy with energy dispersive X-ray spectroscopy was performed on seven common medicinal crop plants, used for tea infusions. The results prompted the need for deeper evaluation, using a more performant analysis method. After calcination of the vegetal matrix, two validated methods were used for the extraction of metals from the ash: A) Aqua Regia mixture and B) diluted hydrochloric acid. The element concentrations from the acid solutions were determined with inductively coupled plasma mass spectrometry. The infusions resulting from these plants were also analyzed to determine the concentration, and thus the percentage, of transferred elements. Our results comply with the previously reported values. The conclusion resulted is that the analzsed medicinal plants with bio accumulative property, cultivated in unpolluted regions, are safe for consumption, however the concentration determination for some toxic metals is advisable.

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1. Introduction

Healing herbs, sacred remedies in ancient times, are widely used likewise today, and are nowadays easily available also for industrial production. Often the use of medicinal plants, especially in teas, disregards the necessary precautions, considering only the benefits. Along with the evolution from harvesting the solitary wild flora to cultivated crops for industrial purposes, and especially because the environment altered by pollution (which directly influences the content of beneficial or dangerous elements in herbs), the research interest for the quality of the medicinal plants and their contaminants is growing constantly [1]. Human organisms are exposed to essential or toxic inorganic forms of the elements by intake of vegetal products, and among them medicinal plants derived products. Recent papers and studies carried unanimously to support the idea of imposing certain regulations for toxic elements contained in medicinal plants [2]. In some of these studies, the principal aim was to determine the potentially bioavailable elements for the human

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health, the water extractable chemical forms of elements in relation to their total level [3]. Many analytical methods were used for the determination of element concentrations in the medicinal plants [1]. Using these various methods, the medicinal plants are scanned for macro elements, microelements, toxic elements, and heavy metals.

The metal tolerance of plants is achieved phenotypically and genotypically, so selecting plants with genetic adaptability for toxic elements, can be a solution for cultivation problems [4]. But an important feature that makes possible hyperaccumulation is exactly the tolerance of the plant for the high concentration of metals. This is achieved by partitioning of metal ions in the plant. Metals can be retained in vacuole compartments, or cell walls and hence have no access to cell sites involved in vital functions such as respiration and cell division [4]. A plant may be called a hyperaccumulator, if the metal concentration in the plant is more than 0.1% of Al, Ca, Co, Cr, Cu, Ni, Se, greater than 0.01% Cd and greater than 1.0% for Zn [5]. Among the medicinal plants mentioned as bio accumulators and even proposed for phytoremediation are named: lavender [6], mint [7], and plantain [8].

The aim of this study was to find a suitable method for expedient element content determination of medicinal crop plants, among them some with bio cumulative properties, and the potential consequences of this phenomenon on their consumption as teas. Thus, the following experimental techniques were tested: SEM/EDS (Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy) as a brief analysis, then an elaborate analysis for mineralization by calcination, followed by dissolution of the residue either in A) Aqua Regia, or B) hydrochloric acid, and finally determination of the metal contents by ICP-MS (Inductively Coupled Plasma Mass Spectrometry).The last method, applied in practice for the quantitative determination of mineral substances, has good sensitivity and detection limits for the analyzed elements. ICP-MS was also implied in the analysis of the infusion extracted metals.

2. Experimental

2.1. Sample preparation

Seven medicinal crop plants (used as raw material for preparing commercial teas and other phyto-pharmaceutical forms), were obtained from S.C. Fares Bio Vital Laboratories S.R.L. Orăștie, cultivated in unpolluted regions, and delivered as air-dried samples. They are as follows: fruits: coriander- *Coriandri fructus (Coriandrum sativum L.*) and dill- *Anethi fructus (Anethum graveolens L.*), aerial part: *Echinaceae herba (Echinacea angustifolia DC.),* flowers: lavender- *Lavandulae flos (Lavandula angustifolia Mill.*) and chamomile- *Matricariae flos (Matricaria chamomilla L.),* leaves: mint - *Menthae folium (Mentha piperita L.*) and plantain- *Plantaginis folium (Plantago lanceolata L.*).

For SEM/EDS analysis the sample must be loose, flat and smooth, that is the reason why the air-dried samples were grounded into a very fine powder. For the ICP-MS analysis, the plants were appropriately milled, and after that dried in an oven at 105ºC to constant mass. The ceramic vessels utilized in the next operation were well washed and cleaned, then calcined at 550 °C for half an hour. The destruction of the vegetable matrix was performed by heating the samples at 550°C for 6 hours in a furnace (type Nabertherm, Bremen, Germany). This is an appropriate and optimum temperature, because in this way the ash reaches a constant mass [9, 10, 11]. The temperature was increased gradually (4 °C/min) to avoid the risk of uncontrolled aggressive combustion of plant material. About 3 g of plant material was subjected to calcination and for each plant two samples were prepared.

2.2. Ash dissolution

Ash dissolution A): 28 mL aqua Regia was added over the ash. To complete the dissolution the mixture was boiled on a hot-plate until in each dish remained about 10 ml of liquid. This method is an adapted version of the microelement extraction method, validated by the Standards Association of Romania (ASRO) (SR ISO 11466:1999) for soils and similar products.

Ash dissolution B): 5 ml of 10% hydrochloric acid was added to the ash and the mixture was boiled on the hot-plate until approximately 2 mL mixture remained into each cup [9, 10, 12].

Even if the hydrochloric acid has lower concentration than the aqua Regia, a complete dissolution of the ash was observed after this operation.

The solutions were transferred quantitatively in 25 mL flasks and then brought to the mark with ultrapure water. After mixing, the obtained solution was filtered through fluted filter (Machery-Nagel, MN 640W). The obtained colourless clear solutions were used to determine the mineral elements by ICP-MS.

2.3. Infusion preparation

2.0 g shredded vegetable plant were added over 200 mL of boiling ultrapure water, after that for 15 minutes the temperature was maintained at 80°C, homogenizing continuously with a magnetic stirrer. After brewing the obtained solution was filtered through filter paper in a 200mL flask, and then brought to the mark with ultrapure water [13]. The resulted clear solution was kept in a refrigerator until the analysis.

2.4. Reagents

The reagents used were of pure analytical grade: 37% hydrochloric acid, 65% nitric acid, and ultrapure water (purified by an Elga procedure). The ICP-MS calibration standard was: Certipur Multi-Element Standard IV for Inductively Coupled Plasma Spectroscopy (ICP), Merck.

2.5. Apparatus

SEM/EDS (Model *Inspect S*, FEI Company) technical characteristics of the device are: voltage: 200 V to 30 kV, current beam >2μA, resolution: <12nm to 3kV in low vacuum mode, focus range 3-99 mm, zoom: 6x>1.000.000x, field of view: the same high and low vacuum. Operating parameters are visible on every SEM image.

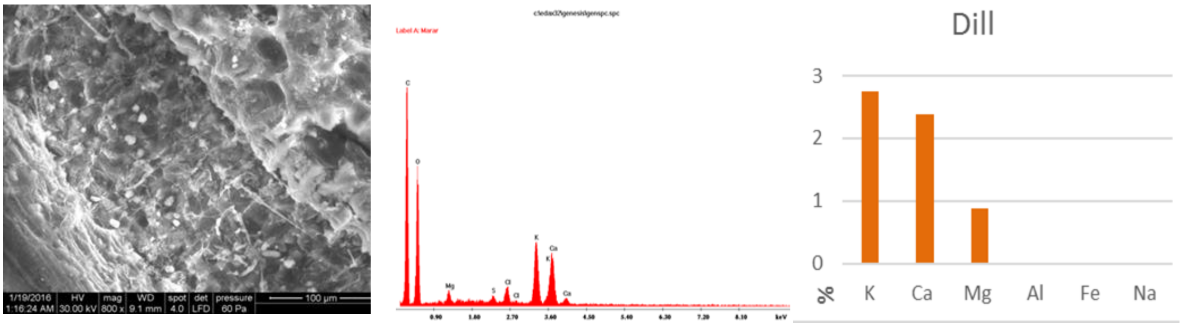
ICP-MS (ICP-MS M90 Aurora, Bruker Daltonics, 2012) measuring device parameters were set as follows: plasma excitation power of 1200 kW, the flow rate of carrier gas (argon): 16.5 L/min, nebulizer gas flow rate (argon): 2 L/min, nebulizer flow: 1L/min, pumping rate 4 rpm, measurement duration: 60 seconds. All readings are replicated five times, the average of the results is considered as the final result.

3. Results and discussions

3.1. SEM/EDS results

Imaging results (Figure 1. a) highlight components of morphological description of the plant, while EDS spectra (Figure 1. b) based on a rapid test provides an overview of the elements contained in the plant [14] and a semi-quantitative determination of the mass percentages (Figure 1. c).

SEM Images | EDS-spectra | Metal content (% weight)

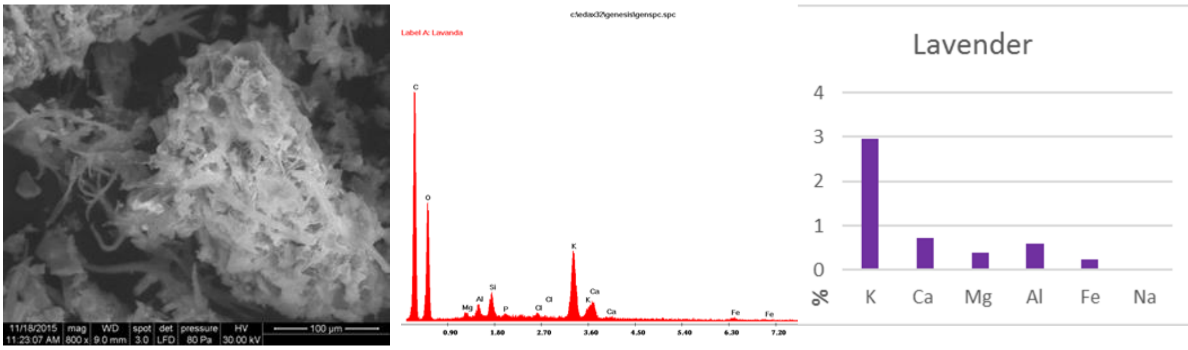


Dill fruits: micromorphology of the exocarp; granular wax crystals can be identified

Dill is reach in Ca and K, and has also trace elements: Mg, Cl and S

Dill fruits: aromatic ingredient in tea, abundant in essential oil, with low heavy metal concentartion.

a) Dill fruits

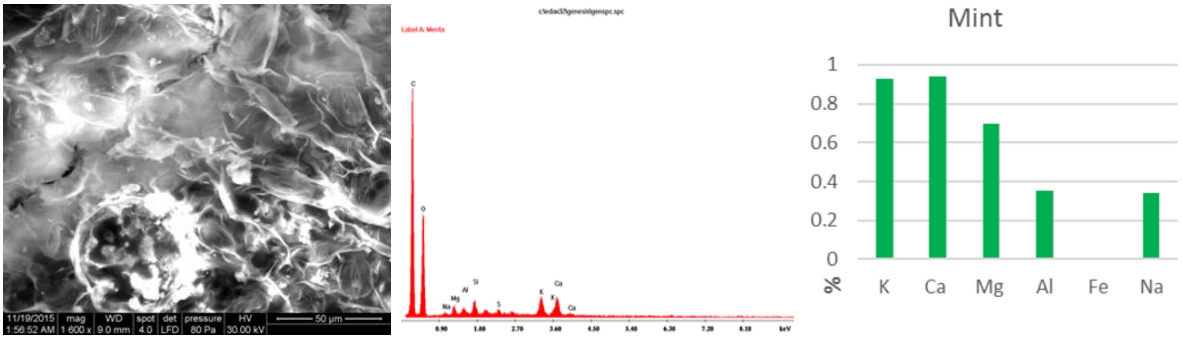


Lavender flowers: tector hairs on the epidermis of lavender sepals

Lavender contains K, Ca, Si, Cl, Mg as beneficial elements;also representative amounts of Al and Fe

Lavender: Al and Fe in comparable concentrations (%) with Ca and Mg raise some worries.

b) Lavender flowers



Mint leaves: epidermal formations, secretory multicellular head with torn cuticle

Mint has macro elements Ca, K in moderate concentration;rich in trace elements: Si, Mg, Al, S an Na.

Mint: uniformed elemental content; Al content is high comparative to the beneficial elements

c) Mint leaves

Fig. 1. a) dill, b) lavender and c) mint characterization through SEM images, EDS spectra, and % weight; limit of detection for EDS is 0.1% weigh (1000 ppm)

Among these three examples, two of them (lavender and mint) have bio cumulative properties, confirmed by the graphics with 0.58% (lavender) and 0.35% (mint) aluminium, equivalent to 5800 ppm and 3500 ppm. In contrast, dill fruits, without accumulative characteristic, are abundant in high concentration for essential elements: potassium, calcium, and magnesium. The relatively elevated Al concentration obtained by EDS for some of the analyzed medicinal plants endorses the interest of searching the implications for tea consumers. Hereinafter the ICP-MS method was implied in metal concentration determinations for the medicinal plants and their infusions.

3.2. ICP-MS

Elemental concentrations of raw material plants are presented in Table 1.

The results obtained by ash dissolution with aqua Regia (a strong oxidizing environment) are higher than the results obtained by simple dissolution of the ash in 10% hydrochloric acid. The concentration of some elements: Ag, B, Be, Bi, Cd, Ga, In, Th, Tl was beyond the limit of detection. These elements have a very low concentration in soils, which can explain the low content, beyond the limit of detection.

The rules set by reference [15] propose maximum amounts permitted in dry plant material for arsenic 1.0 mg/kg, cadmium 0.3 mg/kg and lead 10 mg/kg. In the present work, arsenic and cadmium, below the limit of detection (< 0.08mg/kg) and lead with 1.7 mg/kg comply with the imposed regulations for medicinal plants. This is a safety proof for crop cultivation in unpolluted regions and the safe use of medicinal plants.

The comparison of the obtained results for the macro element potassium with other reported values, 26700 mg/kg for coriander, 20400 mg/kg for chamomile flowers, and 34600 mg/kg for mint leaves, [16] revealed that lower concentrations were obtained in Table 1. For calcium, reference [17] presented higher values: 13431 mg/kg for lavender blossoms and 19016 mg/kg for mint leaves. The highest content of magnesium in Table 1 is obtained for mint leaves, 7605.7 mg/kg, and this concentration is higher than 2316.6 mg/kg [18], 2500 mg/kg [16] and even 6340 mg/kg [17], seeming that the mint leaves can be a good source of magnesium.

*Table 1. Element contents (mg/kg) of studied medicinal plants, mineralized by methods A) and B) and determined by ICP-MS**

Plant	**Coriander (mg/kg)**		**Dill (mg/kg)**		**Echinacea (mg/kg)**		**Lavender (mg/kg)**		**Chamomile (mg/kg)**		**Mint (mg/kg)**		**Plantain (mg/kg)**	
Method	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Ag	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod
Al	28.4	15.6	52.7	35.8	161.4	110.7	2761.2	1760.9	76.7	65.5	380.8	289.1	1671.3	1066.3
As	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod
B	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod
Ba	<lod	2.4	<lod	3.4	<lod	3.0	9.8	6.4	0.1	2.4	21.1	4.4	30.5	5.4
Be	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod
Bi	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod
Ca	5893	5130	9529	7250	22233	17501	8957	5728	5742	4420	11451	7399	10898	9472
Cd	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod
Co	<lod	<lod	<lod	<lod	<lod	<lod	<lod	0.8	<lod	<lod	<lod	<lod	<lod	<lod
Cr	<lod	<lod	<lod	<lod	<lod	<lod	0.6	1.5	<lod	<lod	<lod	<lod	<lod	<lod
Cu	12.4	5.5	6.2	3.4	3.5	2.0	11.7	8.9	4.2	4.8	8.2	8.3	7.6	4.8
Fe	161.7	183.2	246.0	290.4	477.6	599.2	1624	1044	170.0	226.7	519.5	410.1	1162	807.8
Ga	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod
In	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod
K	12282	11092	9798	8311	23054	18282	18682	12879	19314	16028	11298	7828	12778	11396
Li	<lod	2.0	<lod	4.1	<lod	2.0	<lod	7.0	<lod	1.7	<lod	2.2	<lod	0.8
Mg	3625	3664	2629	2381	3900	3179	3333	2231	2400	1941	7606	5269	2816	2507
Mn	31.5	26.0	21.2	17.3	15.8	12.2	80.9	43.7	76.7	59.9	95.6	62.6	82.5	59.7
Na	33.3	10.4	678.0	676.9	30.0	68.9	149.1	176.5	2095.8	1762.6	1101.9	700.1	962.3	924.7
Ni	<lod	2.2	<lod	2.1	<lod	1.7	2.1	2.2	4.2	1.7	2.8	2.7	3.5	2.2
Pb	<lod	<lod	<lod	<lod	<lod	<lod	1.7	<lod	<lod	<lod	1.0	<lod	<lod	<lod
Se	<lod	<lod	<lod	<lod	<lod	9.0	<lod	<lod	<lod	<lod	<lod	<lod	<lod	4.5
Sr	22.3	15.8	63.5	47.8	28.5	19.1	19.6	9.3	9.9	7.0	49.5	32.1	43.0	29.8
Th	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod
Tl	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod	<lod
V	<lod	<lod	<lod	<lod	<lod	<lod	5.4	1.1	<lod	1.0	<lod	<lod	3.3	1.2
Zn	33.2	30.1	12.2	10.6	10.7	15.1	22.6	9.1	18.0	13.5	33.2	18.2	22.6	16.7

*The reported results are the mean of five replicates and the RSD of these replicates, for all the elements was <2%; <lod means below limit of detection (0.08 mg/kg)

Among the micronutrients, Zn content is higher for coriander seeds than the value of 15.98 mg/kg in reference [16]. Mint has the same concentration 33.2 mg/kg as reported by [16, 17], but higher than in [18]. Copper content presents the maximum level for coriander, 12.4 mg/kg, two times higher than reported in [16]. Manganese as a micronutrient, has high values for: mint (95.6 mg/kg), lavender (80.9 mg/kg) and for chamomile (76.7 mg/kg). These are higher than the values reported for mint in [16, 17, 18], lavender in [17], and chamomile in [16, 18]. In Table 1 lavender has the highest concentrations of aluminium and iron: 2761.2 and 2623.9 mg/kg, respectively.

The real biological effects of these element concentrations practically are exerted through the percentage transmitted in infusion. Knowing the element content in infusions, one can determine the water released percentage of every metal, which is actually ingested by humans. Thus, the content of transferred elements in infusions (mg/L) were determined and presented in Table 2. The obtained values are compared with the same type of concentrations from the literature and with the allowed concentration limits for drinking water established for heavy and toxic elements.

For the beneficial elements, the values are compared with the recommended daily intake (RDI) amount, to assess the contribution of these macro elements in the diet by drinking tea. The maximum concentration for calcium is 42.2 mg/L, and it is ten times lower than the higher limit of the range reported in reference [1].By drinking a cup of tea, we can bring a contribution of 1.2% from RDI. The percentage of Ca retrieval in infusions is at least 10.6% for lavender blossoms and up 71.6% for coriander fruits. The richest in Mg is the mint infusion, with a concentration of 37.52 mg/L, and an intake of a cup of mint tea (200 ml) equals to 2.5% of the RDI. The percentage of infusion transmitted Mg is 60.8%. A higher percentage is retrieved in plantain infusion, 70.3%. For potassium, another macro element, the 161 mg/L concentration in the aqueous extract of chamomile, is five times lower than the superior margin of the interval mentioned in the literature. However, the potassium intake by drinking a cup of tea brings only 1% of the RDI. Although the infusion of chamomile is the most concentrated in K, the plant matrix of mint leaves, releases 100% of K, while the coriander fruits only 39.5%. The intake of beneficial elements, K, Ca and Mg by consuming medicinal plants as a tea is welcome, but not sufficient to complete the necessary macronutrients in the diet.

The toxic elements As, Cd, and Pb are mentioned as being under the limit of detection, i.e. 0.01 mg/L. These low concentrations are in agreement with the maximum permissible limits for drinking water. Although drinking water is consumed in greater amounts, minimum 2L water/day is recommended, the herbal infusions are recommended with moderation: 1 - 3 cups/day; this rationale utilizing the limits for drinking water proves the safety of herbal infusions consumption, and that the strategy of medicinal plant crop cultivation in unpolluted areas is beneficial.

A category of trace elements Cr, Cu, Sb, Se were framed with low concentration. Na and Zn, trace elements, with the maximum concentration of 15.3 mg/L Na (for chamomile) and 0.18 mg/L Zn (for mint) are 13 times or 27 times lower than the proposed maximum admitted content and are situated in the first part of the range reported for Na (0.05-80.2) and for Zn (0.017 - 5.30) in reference [1]. Zn is transferred in mint infusion in a proportion of 54.3% and sodium in proportion of 75.0% in coriander infusion.

Table 2. Element content (mg/L) of infusions prepared from crop medicinal plants

Plant	Coriander (mg/L)	Dill (mg/L)	Echinacea (mg/L)	Lavender (mg/L)	Chamomile (mg/L)	Mint (mg/L)	Plantain (mg/L)	Ref. [1] (mg/L)	Maximum Admitted Content (mg/L)	RDI (mg/ day)
Al	<lod	<lod	<lod	0.16	<lod	<lod	0.18	0.006-25.0[a]	0.2[b]	-
As	<lod	<lod	<lod	<lod	<lod	<lod	<lod	0.00002-0.03[a]	0.01[b]	-
Ca	42.2	35	33.2	9.5	15.6	28	40.25	0.01-572[a]	-	700 [c, d]
Cd	<lod	<lod	<lod	<lod	<lod	<lod	<lod	0.00001-0.036[a]	0.005[b]	-
Cr	<lod	<lod	<lod	<lod	<lod	<lod	<lod	0.0003-0.35[a]	0.05[b]	-
Cu	<lod	<lod	<lod	<lod	<lod	<lod	<lod	0.002-0.80[a]	0.1[b]	1.2 [c, d]
Fe	0.60	0.25	0.15	0.98	0.98	0.98	0.98	0.0002-21.4[a]	0.2[b]	8.7 [c, d]
K	48.52	92.2	152	143	161	113	123.2	2.88-852[a]	-	3500 [c, d]
Mg	11.23	10.4	16.23	13.15	14.6	37.52	19.8	0.32-96.1[a]	-	300 [c] 270 [d]
Mn	0.29	<lod	<lod	<lod	0.2	0.2	0.23	0.003-8.90[a]	0.05[b]	-
Na	0.2	4.8	<lod	<lod	15.3	6.48	6.77	0.05-80.2[a]	200[b]	-
Ni	<lod	<lod	<lod	<lod	<lod	<lod	<lod	0.0003-0.42[a]	0.02[b]	-
Pb	<lod	<lod	<lod	<lod	<lod	<lod	<lod	0.000008-0.25[a]	0.01[b]	-
Sb	<lod	<lod	<lod	<lod	<lod	<lod	<lod	0.0001-0.0017[a]	0.005[b]	-
Se	<lod	<lod	<lod	<lod	<lod	<lod	<lod	0.0005-0.02[a]	0.01[b]	0.075 [c] 0.060 [d]
Sr	0.1	0.22	<lod	<lod	<lod	0.11	0.12	0.001-2.34[a]	-	-
V	<lod	<lod	<lod	0.04	<lod	<lod	0.02	0.0025-0.0013[a]	-	-
Zn	0.054	<lod	<lod	<lod	<lod	0.18	<lod	0.017-5.30	5[a]	9.5 [c] 7.0 [d]

* <lod means below limit of detection (0.01 mg/L)

a) According to [1], which have summarized the results of studies from the last 15 years on medicinal plants from different countries

b) Law no. 458/2002 on drinking water quality [19]

c) RDI (recommended daily intake for male and d) female aged from 18 to over 60 years, expressed in mg/day [20]

Only lavender and plantain infusions present a larger quantity of vanadium than the higher limit of 0.0013 mg/L reported by literature. [1] This is due to bioaccumulation capacity of these two plants, and because of the high percentage (73.86% and 60.01%, respectively) transferred in infusions. The TDI (tolerable daily intake) for vanadium, [21] is 0.1 mg/kg body weight, equivalent with 7 mg/day for an adult. Even drinking 1L lavender tea, the vanadium intake is 0.04 mg, far less than the TDI.

Manganese, in the coriander infusion reaches 0.29 mg/L (79.4% of the amount in the raw plant), which is 6 times higher than the limit of 0.05 mg/L for drinking water. Compared with an adult TDI value of 4.2 mg manganese per day (0.06 mg/kg body weight) [22], manganese present in infusions does not represent overdose risks.

Iron, with a maximum concentration of 0.98 mg/L for lavender, chamomile, mint, and plantain infusion, attracts attention because it is five times higher than the imposed limit for water. However, these values are within the range reported for other herb infusions: 0.0002-21.4 mg/L. [1] For iron, the RDI is 8.7 mg/day and TDI is 49 mg/day [21]. The plants with accumulator capacity and contributions to the aqueous extract are lavender, chamomile, mint, and plantain. Even a consumption of 1 L tea per day equals only 1mg/day Fe, i.e. 11% of the RDI, and do not suppose accumulation because the threshold TDI is far distant.

Aluminium, present in large amounts in bulk plants, is transferred in lavender and plantain infusions with the maximum concentration being 0.18 mg/L, below 0.2 mg/L recommended for drinking water. Aluminium is a neurotoxic element, with accumulation risk, and although lavender and plantain have bio accumulative properties, this element is delivered through infusion at a rate of just 0.6 and 1.1%. Another favorable fact is that heavy metals do not influence the development of lavender or essential oil quality and quantity [5]. Bárcena-Padilla and collaborators [23] studied the factors that influence the passage of Al in tea infusions, noting that brewing time, sugar addition and the interaction between ascorbic acid and sucrose are responsible for the growth of Al concentration in tea, and in this way the daily intake of Al is increased. Plant matrix also influence the amount of Al transferred, reaching up to 61.8% [1]. The exact amount of which is likely to be ingested by humans through herbs or herb derivatives is not known exactly. Therefore, recent studies indicate and recommend checking, creating and imposing rules of regulatory limits for Al security in plants to confirm the quality and safety of their products [24, 25, 26].

4. Conclusions

The innovative aspects of the present study cover both the consideration of known metal bio accumulative capacity of the plants, and particularly of the medicinal plants, and the consequences resulting by human ingestion of the infusions (teas), that contain the accumulated elements. The results obtained in this work confirm literature studies that attest the role of lavender, mint and plantain in capturing heavy metals from soil. If the culture is used to extract lavender essential oils, for decorative and aromatherapy purposes, the bio accumulative feature is not a danger for consumers. But if lavender is used as raw material with destination for tea infusions, the problem of ingestion of contaminated products enforce the control of heavy metal concentrations.

Determination of elements through vegetable matrix disintegration with mixed acids and simultaneous determination of all components with ICP-MS is a practical and an affordable quality assessment of raw material from medicinal crop plants, which are used in the manufacture process of phyto pharmaceutical products.

References

[1] P. Pohl, A. Dzimitrowicz, D. Jedryczko, A. Szymczycha-Madeja, M. Welna, P. Jamroz, J. Pharm. Biomed. Anal. **130**, 326 (2016).
[2] G. Schwalfenberg, S. J. Genius, I. Rodushkin, J. Toxicol., Article ID 370460 (2013).
[3] J. Brzezicha-Cirocka, M. Grembecka, P. Szefer, Environ. Monit. Assess. **188**: 183 (2016).
[4] A. Kabata-Pendias, Trace Elements in Soils and Plants, Fourth Edition, CRC Press Ed., (2011).
[5] G. U. Chibuike, S.C. Obiora, Appl. Environ. Soil Sci., Article ID 752708 (2014).
[6] V. R. Angelova, D. F. Grekov, V. K. Kisyov, K. I. Ivanov, Int. J. Biol., Biomol., Agric., Food Biotechnol. Eng. **9**, 522 (2015).
[7] V. D. Zheljazkov, L. E. Craker, B. Xing, Environ. Exp. Bot. **58**, 9 (2006).
[8] A. A. Romeh, M.A.Khamis, S.M.Metwally, Water Air Soil Pollut. **227**, 9 (2016).
[9] D. S. Antal, V. Vlaia, C.A. Dehelean, L. Vlaia, C. Trandafirescu, F. Ardelean, I. Pînzaru, D. Ionescu, Rev. Chim.(Bucharest) **66(**2), 236 (2015).
[10] M. E. Petenatti, E. M. Petenatti, L. A. Del Vitto, M. R. Téves, N. O. Caffini,

E. J. Marchevsky, R. G. Pellerano, Braz. J. Pharmacogn. **21(**6), 1144 (2011).
[11] L. Aldras-Garcia, M.A. Zapata-Revilla, M.D. Tenorio-Sanz, J. Food Nutr. Res. **52(**3), 172 (2013).
[12] K. Pytlakowska, A. Kitap, P. Janoska, M. Polowniak, V. Kozik, Food Chem. **135**, 494 (2012).
[13] P. Konieczynski, M. Wesolowski, I. Radecka, P. Rafalski, Chem. Speciat. Bioavailab. **23(**2), 61 (2011).
[14] M. Tomašević, M. Aničić, Facta Univ., Series: Phys., Chem. Technol. **8,** 1 (2010).
[15] WHO, Quality control methods for medicinal plant materials, World Health Organization Geneva, 1998.
[16] M. Zengin, M. M. Özcan, Ü. Çetin, S. Gezgin, J. Sci. Food Agric. **88**, 581 (2008).
[17] A. Szymczycha-Madeja, M. Welna, W. Zyrnicki, J. Braz. Chem. Soc. **24(**5),777 (2013).
[18] M.M. Özcan, A. Ünver, T. Ucar, D. Arslan, Food Chem. **106**, 1120 (2008).
[19] https://www.google.ro/webhp?sourceid=chrome-instant&rlz=1C1VASM_enRO529HU533&ion=1&espv=2&ie=UTF-8#q=13.%09mmediu.ro%2Fnew%2Fwp...%2FLegislatie%2F1...Calitatea%2520apei%2F...%2FLegea%2520458_2002.doc (accesed January, 2017).
[20] G. B. M. Mensink, R. Fletcher, M. Gurinovic, I. Huybrechts, L. Lafay, L. Serra-Majem, L. Szponar, I. Tetens, J. Verkaik-Kloosterman, A. Baka, A.M. Stephen, Brit. J. Nutr. **110**, 755 (2013).
[21] M. K. Anke, Essential and Toxic Effects of Macro, Trace, and Ultratrace Elements in the Nutrition of Man, In: Merian E, Anke M, Ihnat M, et al (Eds.). Elements and their Compounds in the Environment, 2nd Ed., Weinheim: Wiley VCH, 2004, 343-367.
[22] ANONYMOUS, Manganese in Drinking-water. Background document for development of WHO Guidelines for Drinking-water Quality, World Health Organization, 2011 http://www.who.int/water_sanitation_health/dwq/chemicals/manganese.pdf .
[22] D.A. Bárcena-Padilla, M. Bernal-González, A. Panizza-de-León, R. S. García-Gómez, C.Durán-Domínguez-de-Bazúa, Nat. Resour. **2,** 141 (2011).
[23] C. Rubio, J.R.D. Lucas, A. J. Gutiérrez, D. Glez-Weller, B. Pérez Marrero, J. M. Caballero, C. Revert, A. Hardisson, J. Pharm. Biomed. Anal., **71**, 11 (2012).
[24] J. Malik, A. Frankova, O. Drabek, J. Szakova, C. Ash, L. Kokoska, Food Chem. **139**, 728 (2013).
[25] J. Malik, J. Szakova, O. Drabek, J. Balik, L. Kokoska, Food Chem. **111**, 520 (2008).