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COMPARATIVE STUDY OF THE BIOACCUMULATION OF HEAVY METALS IN LAVENDER PLANTS

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The present study measures the concentration of several metals (heavy, alkaline and alkaline earth) in lavender plants cultivated in polluted areas in the city of Bucharest (Tineretului Boulevard, Unirii Boulevard, Berceni Boulevard). For comparison purposes lavender plants from areas considered of zero pollution were as well analyzed. The concentrations of heavy metals such as Cd, As, Pb, Cu, Mn, Zn, Co, Ni and Fe in the plant samples and in the soil samples were measured using Inductive Coupled Plasma - Optical Emission Spectrometer. The concentrations of Cr, Mn and Fe are higher in the soil from the polluted areas. The concentrations of Cr, Cu, Mn, Zn and Fe are higher in plants from polluted areas. This denotes the lavender suitability for heavy metal phytoremediation.

Keywords: heavy metals, soil pollution, bioaccumulation

1. Introduction

The soil is an environment that is accumulating different pollutants among which are the heavy metals. From soil, heavy metals can enter through food chain in the human body and accumulate in tissues and organs. Based on their effect on living organisms, heavy metals can be classified in two categories: essentials and non-essentials. In the first category are included the metals that are part of the biological processes (e.g. they can bound to different enzymes). In low quantities their effect to the living organism is beneficial (e.g. Fe, Zn, Cu, Co) [1 – 6]. Non-essential heavy metals (like Pb, As, Cd, Hg, Cr) have a negative impact, they are extremely toxic for the living organisms even at very low concentrations [7].

The heavy metals interact with substances in the environment to form compounds with different stability and properties. This stability is a measure of the binding strength with the other compounds and has a direct effect on the

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biological availability of heavy metals [8]. These compounds are divided in different chemical fractions [9 – 11]:

(i) F1 water soluble fraction: includes all the compounds that are adsorbed on the surface of the particles and can be quickly released in the solution.
(ii) F2 mobile fraction: easily exchangeable fraction, can be adsorbed on other solid components (e.g. clay minerals or humus).
(iii) F3 carbonate fraction: heavy metals that are in the form of carbonate or bound with carbonate (e.g. co-precipitated with it); can be easily released in favorable conditions.
(iv) F4 humic acid fraction: heavy metals in the residues.
(v) F5 iron - manganese oxide fraction: in oxidizing conditions it passes to F1 and F2.
(vi) F6 strong organic fraction.
(vii) F7 residual fraction: stable compounds like silicates, cements, and oxide crystal structures.

The bioavailability index is defined as the sum of the first three concentrations, and it is used in the assessment the mobility of heavy metals. The higher the bioavailability index, the higher the transfer to plants, finally increasing the impact on human health [9]. Fractions F4 to F6 could become available in strong acid environments [10].

The fractions F2 and F3 are generated mainly from human activities [11].

It has been shown that road traffic can significantly contribute to heavy metals accumulation in soil and be transferred to plants (e.g. vegetables and legumes, *Plantango major*) [12 – 15].

Medicinal plants are known to be either metal hyperaccumulators or metal excluders [16, 17]. Goretti et al., (2020) investigated the level of heavy metals in honey bees to estimate the contamination level of plants [18]. Trees (*Platanus orientalis L.* and *Pinus nigra Arn*) have been used as a bioindicator for the estimation of air pollution with heavy metals [19].

Lavender is used for its aromatic properties in cosmetics and perfume industry [20 – 22], in food industry [23 – 25], as a natural insecticide [26]. Since few years it started to be used also in medicine thanks to its healing effects (in neurological disorders like epilepsy, depression, anxiety, migraine, and Alzheimer's disease, as anti-inflammatory product, treatment of sleeping disorders, pain reducer) [27 – 32]. The lavender properties are given by a mixture of compounds that include terpenes, (linalool, limonene, triterpenes, linalyl acetate), alcohols, ketones, polyphenols, coumarins, cineole, and flavonoids, etc [33, 34].

In this context, to evaluate whether lavender plants (*Lavandula angustifolia*) are susceptible to accumulate heavy metals deposited in the soil from the road dust, analyzes of plants and soil were compared from different polluted areas.

2. Materials and methods

Samples of plants and polluted soil were taken from the city of Bucharest from different intersections, in areas with intense traffic (Unirii Boulevard, Berceni Boulevard, Tineretului Boulevard). For comparison purposes, soil samples from areas considered zero pollution (Moara Domneasca in Ilfov County and University of Agronomic Sciences and Veterinary Medicine of Bucharest, USAMV) were withdrawn. These samples were dried in an oven (or lyophilizer) and prepared for mineralization/acid digestion.

Samples preparation

To obtain accurate results of plant or soil analysis, the complete digestion of the sample is necessary. Digestion method of plant and soil samples in an open system was used for samples preparation.

Open system digestion is still widely used for the samples decomposition and the destruction of organic matter.

The extraction of metals from the lavender plants was carried out by an acid digestion procedure as follows: an amount of approximately 1 g of plant was dried at lyophilizer and crushed. The samples were mineralized with a mixture of ultra-pure HNO_3 and H_2O_2 in a ratio of 10:3 (v/v), for 24 hours, at room temperature to destroy the organic matter (cold digestion). The samples thus obtained were filtered and the acid extracts were diluted with ultrapure water to a constant volume of 25 mL.

The content of metals in the soil was determined from approximately 1.5 g of sieved and previously dried soil sample. The drying was made in an oven at a maximum of 50º C. To the soil sample it was added a mixture of 5 mL of ultrapure nitric acid (HNO_3) 65% and 15 mL ultrapure hydrochloric acid (HCl) 37% (extraction in royal water). The samples were filtered and diluted with ultrapure water to a constant volume of 50 mL.

Quantitative analysis method

The metals in the samples of soil and plants were determined by atomic spectroscopy using an inductively coupled plasma optical emission spectrometer ICP –OES Avio 500 Perkin Elmer, equipped with UV–VIS detectors and axial plasma view.

Reagents

High quality water was obtained through an MilliQ Ultrapure water purification system with ELIX Technology.

For the soil and plants samples preparation, the following reagents and chemicals were used: hydrochloric acid 37%; nitric acid ultrapure grade 69% (Merck); hydrogen peroxide 30% (Merck).

3. Results and discussion

Natural levels of Cu, Ni, Pb, and Zn in the soils from areas of zero pollution correspond to slightly higher values than the normal values from the normative 756/97. For the polluted soils, according to data presented in Table 1, the concentrations for Cu, Ni, Pb, and Zn are higher than the limits imposed by the normative 756/97.

Table 1

Soil composition

Compound	Contaminated soil		Uncontaminated soil		Reference values for chemical elements in soil, Order 756/97 "Regulations regarding environmental pollution assessment", mg/kg dried matter Normal values [35]
	Unirii Boulevard, mg/kg dried matter	Berceni Boulevard, mg/kg dried matter	Moara Domneasca mg/kg dried matter	U.S.A.M.V mg/kg dried matter	
As	<2.50	<2.50	<2.50	<2.50	**5**
Cd	0.24	0.31	0.34	0.54	**1**
Co	9.03	9.01	8.51	7.61	**15**
Cr	24.8	30.5	20.24	16.34	**30**
Cu	26.7	34.6	32.67	27.48	**20**
Fe	29603	34791	9970.2	9539.9	**-**
Mn	848	717	543.2	493.4	**900**
Mo	<0.80	<0.80	<0.80	<0.80	**2**
Ni	26.9	32.6	21.86	20.92	**20**
Pb	28.2	36.3	28.58	35.56	**20**
Sb	4.97	5.00	<3.00	<3.00	**5**
Se	Not analyzed	Not analyzed	<2.00	<2.00	
Zn	71.6	88,6	62.23	206.13	**1**
Ca	11068	11064	5579.24	9943.55	**100**
Mg	5526	5728	3116.79	3269.06	**-**
Na	95.1	124	47.67	113.51	**-**
K	4445	4480	2518.97	1805.59	**-**
Al	13763	16130	9195.47	8309.95	**-**

The Cr and Sb are at the value given in the soil normative but are significantly higher than the values from the areas of zero pollution. Although they do not exceed the normative values, Cr, Fe and Mn are significantly higher than the levels in areas of zero pollution. Higher values of alkaline and alkaline earth metals are also reported in the polluted soils. Therefore, Cr, Pb, Mn, Fe, Ni, Sb are the main metals that are susceptible to pollute the analyzed soil.

According to Tables 2 and 3, the lavender plants in areas of zero pollution contain undetectable levels of As, Cd, Co, Pb and Sb.

Table 2

Lavender plant composition – area of zero pollution

Moara Domneasca Ilfov County– mg/kg dried matter (2022)			
Compound	Whole Plant	Stem	Flower
As	<0.75	<0.75	<0.75
Cd	<0.08	<0.08	<0.08
Co	<0.04	<0.04	<0.04
Pb	<1.50	<1.50	<1.50
Sb	<0.18	<0.18	<0.18

Table 3

Lavender plant composition – area of zero pollution

U.S.A.M.V. – mg/kg dried matter (2022)			
Compound	Whole Plant	Stem	Flower
As	<0.75	<0.75	<0.75
Cd	<0.08	<0.08	<0.08
Co	<0.04	<0.04	<0.04
Pb	<1.50	<1.50	<1.50
Sb	<0.18	<0.18	<0.18

Lavender plant composition in polluted area is presented in Tables 4, 5 and 6. Like in the case of lavender plants from areas of zero pollution, the plants in polluted zones also show undetectable levels of As, Cd, Co, Pb and Sb (Tables 4 and 5).

Table 4

Lavender plant composition – polluted area

Tineretului Boulevard – mg/kg dried matter (2023)			
Compound	Whole Plant	Stem	Flower
As	<0.75	<0.75	<0.75
Cd	<0.08	<0.08	<0.08
Co	<0.04	<0.04	<0.04
Pb	<1.50	<1.50	<1.50
Se	<0.18	<0.18	<0.18

Table 5

Lavender plant composition – polluted area

Unirii Boulevard – mg/kg dried matter (2023)			
Compound	Whole Plant	Stem	Flower
As	<0.75	<0.75	<0.75
Cd	<0.08	<0.08	<0.08
Co	<0.04	<0.04	<0.04
Pb	<1.50	<1.50	<1.50
Se	<0.18	<0.18	<0.18

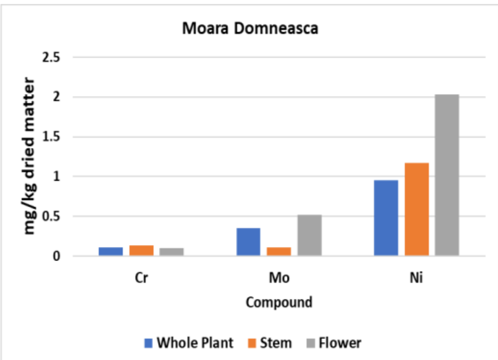
Table 6

Lavender plant composition – polluted area

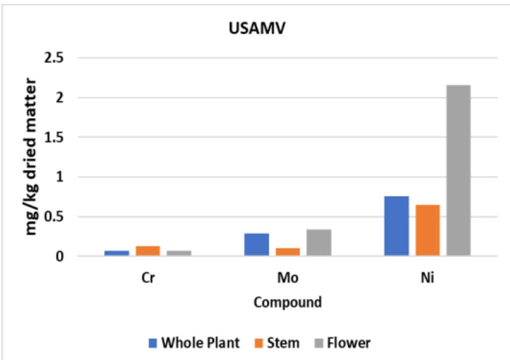
Whole plant – mg/kg dried matter (2022)			
Compound	Unirii Boulevard	Berceni Boulevard	Berceni street
Cr	0.73	0.78	0.36
Cu	7.95	8.10	6.18

Fe	245.4	352	142
Mn	17.4	22.5	18.8
Mo	0.36	0.15	0.13
Ni	1.32	1.61	1.08
Pb	2.03	<1.50	<1.50
Sb	<0.18	0.36	<0.18
Zn	23.2	22.5	19.7
Ca	9274	11193	8039
Mg	2211	2721	1428
Na	24.6	189	76.3
K	14357	18472	17444
Al	79.3	147	58.2

When analyzing the ionic metals levels in the whole plant in three polluted areas (Unirii Boulevard, Berceni Boulevard and Berceni street), the lowest content in heavy metals (Cr, Cu, Fe, Ni, Pb and Zn) show the plants from Berceni street (Table 6). In Fig. 1 is presented the composition of lavender plants from areas of zero pollution available for the year 2022.



(a)



(d)

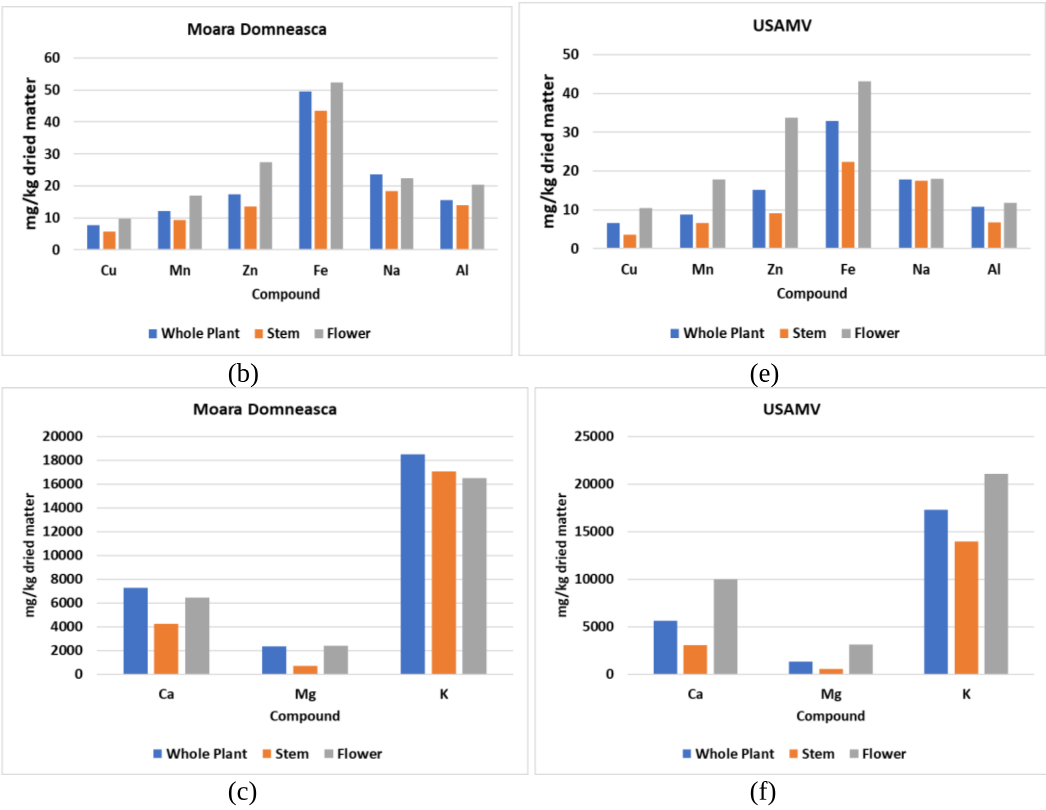
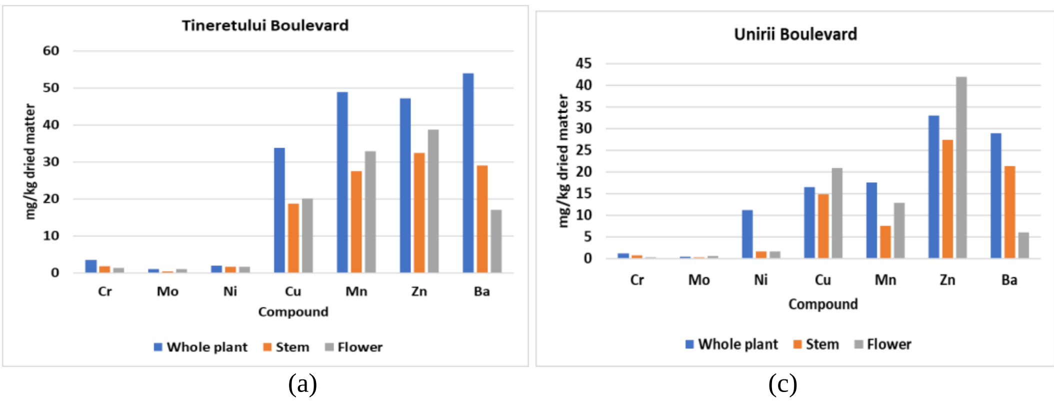
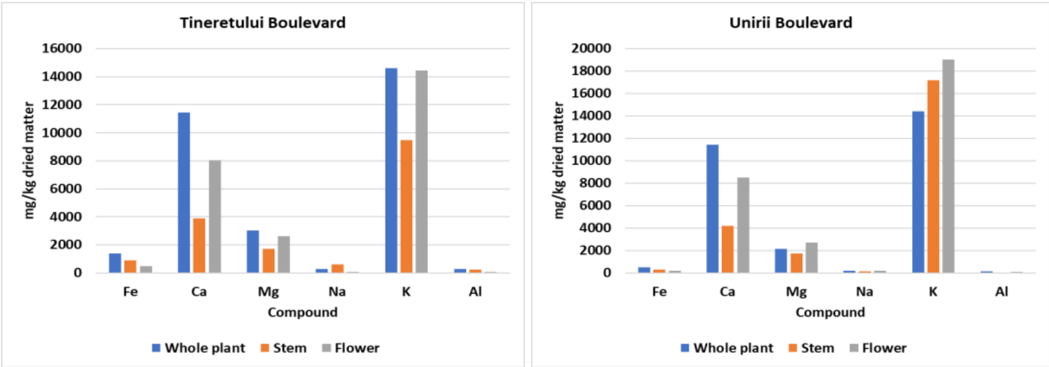


Fig. 1. Composition of lavender plants from areas of zero pollution (2022): (a), (b) and (c) Moara Domneasca, Ilfov County, (d), (e) and (f) USAMV

When analyzing the different parts of the plant, it can be seen that flowers tend to accumulate more heavy metals (Ni, Mo, Cu, Mn, Zn, and Fe) than the stem part (Fig. 1).

In Fig. 2 is presented the composition of lavender plants from polluted areas.





(b) (d)

Fig. 2. Composition of lavender plants from polluted areas (2023): (a) and (b) Tineretului Boulevard, (c) and (d) Unirii Boulevard

Although, the soil analysis indicated contents of chromium below the normal values, the plants in the polluted areas accumulate this heavy metal. The content of chromium in plants from polluted areas are more than 10 times higher than in plants cultivated in areas of zero pollution. There are also differences between the to polluted areas with more chromium accumulated in the plants analyzed from Tineretului Boulevard compared to Unirii Boulevard. Manganese, copper and iron are also a few times higher in the plants from Tineretului Boulevard compared to Unirii Boulevard.

6. Conclusions

Soil analysis indicated that Cr, Fe and Mn levels are significantly higher in the soils from polluted areas (Unirii Boulevard and Berceni Boulevard) than in areas of zero pollution (Moara Domneasca and USAMV). They are however close to the values indicated in the normative 756/97 regarding environmental pollution assessment.

Despite this fact the plants cultivated in polluted areas accumulate Cr, Cu, Fe, Mn, Mo and Zn at levels a few times higher than the levels in plants from zero pollution areas. All analyzed plants do not accumulate Pb, even if its concentration in all the types of soil overpasses the normal value indicated in the normative 756/97. The flowers are accumulating more Ni, Mo, Cu, Mn, Zn, and Fe, than the other parts of the plant. Lavender susceptibility to accumulate heavy metals means that the soil for lavender cultivation must contain low levels of heavy metals when the plant is used for medical, cosmetic or food purposes.

Future studies aim to determine how much of the heavy metals contained in the lavender plant are transferred to the alcoholic extracts of essential oils.

Due the bioaccumulation capacity of some heavy metals, the lavender could also be used for the phytoremediation of polluted soils. This remain however a high cost option for soil phytoremediation considering that are other plants that naturally grow on the fields and have a superior bioaccumulation capacity (e.g. *Plantago major*).

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R E F E R E N C E S

[1]. *J. Chen, L. A Calderone, L. Pan, T. Quist, M.E. Pandelia,* The Fe and Zn cofactor dilemma, in BBA - Proteins and Proteomics, **vol. 1871**, 2023, 140931.
[2]. *R.A. Festa, D.J. Thiele,* Copper: an essential metal in biology, in Current Biology, **vol. 21**, no. 21, 2011, R877–R883.
[3] *E. Kim, S. A. Ham, J. S. Hwang, J. P. Won, H. G. Lee, J. Hur, H. G. Seo*, Zinc finger protein 251 deficiency impairs glucose metabolism by inducing adipocyte hypertrophy, in Molecular and Cellular Endocrinology, **vol. 562**, 2023, 111838.
[4]. *E. Z. Sim, T. Enomoto, N. Shiraki, N. Furuta, S. Kashio, T. Kambe, T. Tsuyama, A. Arakawa, H. Ozawa, M. Yokoyama, M. Miura, S. Kume,* Methionine metabolism regulates pluripotent stem cell pluripotency and differentiation through zinc mobilization, in Cell Reports, **vol. 40**, 2022, 111120.
[5]. *L. O. Simonsen, H. Harbak, P. Bennekou*, Cobalt metabolism and toxicology—A brief update, in Science of the Total Environment **vol. 432**, 2012, 210–215.
[6]. *C. Cabrera, C. Frisk, U. Lofstrom, P. Lynga, C. Linde, C. Hage, H. Persson, M.J. Eriksson, H. Wallen, B. Persson, M. Ekstrom*, Relationship between iron deficiency and expression of genes involved in iron metabolism in human myocardium and skeletal muscle in International Journal of Cardiology, **vol. 379**, 2023, 82–88.
[7]. *J.-J. Kim, Y.-S. Kim, V. Kumar.* Heavy metal toxicity: An update of chelating therapeutic strategies, in Journal of Trace Elements in Medicine and Biology, **vol. 54**, 2019, 226–231.
[8]. *Q. Yang, L. Zhang, H. Wang, J. Delgado Martín.* Bioavailability and health risk of toxic heavy metals (As, Hg, Pb and Cd) in urban soils: A Monte Carlo simulation approach, in Environmental Research, **vol. 214**, 2022, 113772.
[9]. *A. Mishra, S. Pervez, M. Verma, C. Candeias, Y. F. Pervez, P. Dugga, S. R. Verma, I. Karbhal, K. K. Ghosh, M. K. Deb, M. L. Satnami, K. Shrivas, A. Tamrakar.* Chemical fractionation of particulate-bound metal(loid)s to evaluate their bioavailability, sources and associated cancer risk in India, in Science of the Total Environment, **vol. 857**, 2023, 159516.
[10]. J. Zhang, H. Li, Y. Zhou, L. Dou, L. Cai, L. Mo, J. You. Bioavailability and soil-to-crop transfer of heavy metals in farmland soils: A case study in the Pearl River Delta, South China, in Environmental Pollution, **vol. 235**, 2018, 710–719.
[11]. *B. Hu, P. Guo, H. Su, J. Deng, M. Zheng, J. Wang, Y. Wu, Y. Jin*. Fraction distribution and bioavailability of soil heavy metals under different planting patterns in mangrove restoration wetlands in Jinjiang, Fujian, China, in Ecological Engineering, **vol. 166**, 2021, 106242.

[12]. *G. Nabulo, H. Oryem-Origa, M. Diamond.* Assessment of lead, cadmium, and zinc contamination of roadside soils, surface films, and vegetables in Kampala City, Uganda, in Environmental Research, **vol. 101**, 2006, 42–52.

[13]. *M. N. Alyemeni, I. A.A. Almohisen.* Traffic and industrial activities around Riyadh cause the accumulation of heavy metals in legumes: A case study, in Saudi Journal of Biological Sciences, **vol. 21**, 2014, 167-172.

[14]. *T. M. Galal, H. S. Shehata*. Bioaccumulation and translocation of heavy metals by Plantago major L. grown in contaminated soils under the effect of traffic pollution, in Ecological Indicators, **vol. 48**, 2015, 244–251.

[15]. *A. Nadgorska-Socha, M. Kandziora-Ciupa, M. Trzesicki, G. Barczyk*. Air pollution tolerance index and heavy metal bioaccumulation in selected plant species from urban biotopes, in Chemosphere, vol. 183, 2017, 471–482.

[16]. *E. Masarovicova, K. Kralova, M. Kummerova*. Principles of classification of medicinal plants as hyperaccumulators or excluders, in Acta Physiol. Plant, **vol. 32**, 2010, 823–829.

[17]. *D. Malizia, A. Giuliano, G. Ortaggi, A. Masotti.* Common plants as alternative analytical tools to monitor heavy metals in soil, in Chemistry Central Journal, **vol. 6** (Suppl 2), 2012, S6.

[18]. *E. Goretti, M. Pallottini, R. Rossi, G. La Porta, T. Gardi, B.T. Cenci Goga, A.C. Elia, M. Galletti, B. Moroni, C. Petroselli, R. Selvaggi, D.* Cappelletti. Heavy metal bioaccumulation in honey bee matrix, an indicator to assess the contamination level in terrestrial environments, in Environmental Pollution, **vol. 256**, 2020, 113388.

[19]. *T. Sawidis, J. Breuste, M. Mitrovic, P. Pavlovic, K. Tsigaridas.* Trees as bioindicator of heavy metal pollution in three European cities, in Environmental Pollution, **vol. 159**, 2011, 3560–3570.

[20]. *D. Andrys, M. Adaszyńska-Skwirzyńska, D. Kulpa.* Essential oil obtained from micropropagated lavender, its effect on HSF cells and application in cosmetic emulsion as a natural protective substance, in Natural Product Research, **vol. 32**, 2018, 849-853.

[21]. *N. M. Ajorpaz, Z. Rahemi, M. Aghajani, S. H. Hashemi*. Effects of glycerin oil and lavender oil massages on hemodialysis patients' restless legs syndrome, in Journal of Bodywork and Movement Therapies, **vol. 24,** 2020, 88-92.

[22]. *M. Kazemi, M. Mohammadifar, E. Aghadavoud, Z. Vakili, M. H. Aarabi, S. A. Talaei*. Deep skin wound healing potential of lavender essential oil and licorice extract in a nanoemulsion form: Biochemical, histopathological and gene expression evidences, in Journal of Tissue Viability, **vol. 29**, 2020, 116-124.

[23]. *M.-R. Bazrafshan, M. Jokar, N. Shokrpour, H. Delam.* The effect of lavender herbal tea on the anxiety and depression of the elderly: A randomized clinical trial, in Complementary Therapies in Medicine, **vol. 50**, 2020, 102393.

[24]. *I. Escriche, L. Sobrino-Gregorio, A. Conchado, M. Juan-Borrás.* Volatile profile in the accurate labelling of monofloral honey. The case of lavender and thyme honey, in Food Chemistry, **vol. 226**, 2017, Pages 61-68.

[25]. *A. Pascual-Maté, S. M. Osés, G. L. Marcazzan, S. Gardini, M. A. Fernández Muiño, M. T. Sancho*. Sugar composition and sugar-related parameters of honeys from the northern Iberian Plateau, in Journal of Food Composition and Analysis, **vol. 74**, 2018, 34-43.

[26]. *A. Jiang, Y. Cai, Y. Yang, H. Wang, Z. She, C. Xu, Z. Tai.* Temperature-regulated microcapsules containing lavender essential oil are effective natural insecticide against Sitophilus granaries in Industrial Crops and Products, **vol. 203**, 2023, 117186.

[27]. *A. M. Sayed, S. Morsy, G. M. Tawfik, S. Naveed, N. T. Minh-Duc, T. H. Hieu, Z. A. Ali, A. Shinkar, M. F. Doheim, M. R. Hashan, N. T. Huy.* The best route of administration of lavender for anxiety: a systematic review and network meta-analysis, in General Hospital Psychiatry, **vol. 64**, 2020, 33-40.

[28]. *N. H. Bavarsad, S. Bagheri, M. Kourosh-Arami, A. Komaki.* Aromatherapy for the brain: Lavender's healing effect on epilepsy, depression, anxiety, migraine, and Alzheimer's disease: A review article, in Heliyon, **vol. 9**, 2023, e18492.
[29]. *A. Shamabadi, A. Hasanzadeh, A. Ahmadzade, H. Ghadimi, M. Gholami, S. Akhondzadeh.* The anxiolytic effects of Lavandula angustifolia (lavender): An overview of systematic reviews, in Journal of Herbal Medicine, **vol. 40**, 2023, 100672.
[30]. *W. E. Müller, G. Sillani, A. Schuwald, K. Friedland*. Pharmacological basis of the anxiolytic and antidepressant properties of Silexan®, an essential oil from the flowers of lavender, in Neurochemistry International, **vol. 143**, 2021, 104899.
[31]. *L. Lucena, J. G. Santos-Junior, S. Tufik, H. Hachul.* Effect of a lavender essential oil and sleep hygiene protocol on insomnia in postmenopausal women: A pilot randomized clinical trial, in Explore, 2023, article in press, https://doi.org/10.1016/j.explore.2023.07.004.
[32]. *N. Razaghi, S. Z. Aemmi, A. S. S. Hoseini, H. Boskabadi, T. Mohebbi, M. Ramezani.* The effectiveness of familiar olfactory stimulation with lavender scent and glucose on the pain of blood sampling in term neonates: A randomized controlled clinical trial, in Complementary Therapies in Medicine, **vol. 49**, 2020, 102289.
[33]. *Y. Xu, Li Ma, F. Liu, L. Yao, W. Wang, S. Yang, T. Han*. Lavender essential oil fractions alleviate sleep disorders induced by the combination of anxiety and caffeine in mice, in Journal of Ethnopharmacology, **vol. 302**, 2023, 115868.
[34]. *P. K. Khatri, M. Paolini, R. Larcher, L. Ziller, D.A. Magdas, O. Marincas, A. Roncone, L. Bontempo.* Validation of gas chromatographic methods for lavender essential oil authentication based on volatile organic compounds and stable isotope ratios, in Microchemical Journal, **vol.186**, 2023, 108343.
[35]. Order 756/97 "Regulations regarding environmental pollution assessment", mg/kg dried matter.