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HEAVY METAL CONTENT IN VEGETABLE GARDEN SOILS IN RELATION TO THEIR NATURAL BACKGROUND

VSEBNOST TEŽKIH KOVIN V TLEH IZBRANIH KMETIJSKIH POVRŠIN V POVEZAVI Z NJIHOVIM NARAVNIM OZADJEM

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Keywords: *soil contamination, soil degradation, food safety, allotment gardens, soil pollution*

Abstract

Heavy metals (HM) are present in soil naturally *[1]*, due to the weathering of the element-rich parent rock and by anthropogenic sources (industry, energy production, agriculture, traffic) *[2–4]*. The agricultural sources of increased HM concentrations in soil are HM-containing fertilizers and pesticides. Agricultural soils are often considered polluted, and are therefore subject to soil contamination monitoring for food safety reasons. Allotments are particularly at risk from intensive gardening, the general overuse of fertilizers, soil conditioners, often seen as a means of improving soil quality, in some cases the overuse or misuse of pesticides and, in the past, the use of coal ash. In some cases, landowners are also receiving untested and potentially polluted soils from elsewhere. Therefore, the soils of the vegetable/allotment gardens are generally considered to be 'highly anthropogenized'. According to Slovenian legislation *[5]*, the HM concentration is considered elevated if the HM concentration in the soil is above the limit immission value (LIV), polluted if it is above the warning immission value (WIV) and critically polluted if it is above the critical immission value (CIV). The HM content was analyzed in the soils of 20 allotment gardens

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in the village of Legen (Municipality of Slovenj Gradec, Carinthia, Slovenia). The soil samples were dried, ground and sieved in the FEP laboratory, and analyzed ‘by Bureau Veritas Commodities (Canada) using Aqua Regia extraction to determine the 'pseudo-total content' for 37 elements (Ag, Al, **As**, Au, B, Ba, Bi, Ca, **Cd**, **Co**, **Cr**, **Cu**, Fe, Ga, **Hg**, K, La, Mg, **Mn**, Mo, Na, **Ni**, P, **Pb**, S, Sb, Sc, Se, Sr, Te, Th, Ti, TI, U, V, W, and **Zn**), 10 of which (in the frames) are considered common HM soil contaminants. The comparison of the HM concentrations in the garden soils with the well-known rich natural geochemical background of the area showed that the values for all the compared metals, except Al, Fe, Ga, Sc, Th and Co, were higher than natural element backgrounds in the Eastern Alps and in Slovenia as a whole. The HM concentrations in the garden soils were within, or slightly above, the natural background values *[1]*, but below the LIV, with the exception of Pb and Zn in four gardens, where the concentrations exceeded the WIV *[6]*. The garden soils in the Legen village area have been enriched anthropogenically, most likely by the introduction of manure, and, in one case, untested and contaminated soils from elsewhere. Most of the gardens are characteristically oversupplied with the nutrients P and K; the soils are moderately enriched with soil organic matter and have an average acidity of pH 6.7, which means that the soil is neutral.

Povzetek

Težke kovine (TK) so v tleh naravno prisotne *[1]* predvsem zaradi preperevanja matičnih kamnin, bogatimi z elementi, in antropogenih virov (industrija, energijska proizvodnja, kmetijstvo in promet) *[2-4]*. Kmetijski vir povišanih koncentracij TK v tleh je uporaba raznih gnojil in pesticidov, ki vsebujejo TK. Kmetijska tla pogosto veljajo za onesnažena, ravno zato pa so zaradi varnosti hrane vključena v monitoring talne onesnaženosti. Vrtovi so še posebej ogroženi zaradi intenzivnega vrtnarjenja, splošne pretirane uporabe gnojil in drugih dodatkov, ki naj bi izboljšali kakovost tal, v nekaterih primerih prekomerne ali napačne uporabe pesticidov ter uporabe premogovega pepela v preteklosti. V določenih primerih lastniki zemljišč uporabljajo netestirana in potencialno onesnažena tla od drugod. Zato na splošno velja, da so tla vrtov »močno antropogena«. V skladu s slovensko zakonodajo *[5]* koncentracija TK velja za povišano, kadar koncentracija TK v tleh preseže mejno imisijsko vrednost (MIV), za onesnaženo, če preseže opozorilno imisijsko vrednost (OIV), in za kritično onesnaženo, kadar preseže kritično imisijsko vrednost (KIV). Analizirali smo vsebnost TK v tleh 20 vrtov v vasi Legen (občina Slovenj Gradec, Koroška). Talni vzorci so bili posušeni, zmleti in presejani v laboratoriju FVO ter analizirani v Bureau Veritas Commodities (Kanada) z uporabo ekstrakcijske metode Aqua Regia za določanje navidezne skupne vsebnosti 37 elementov (Ag, Al, **As**, Au, B, Ba, Bi, Ca, **Cd**, **Co**, **Cr**, **Cu**, Fe, Ga, **Hg**, K, La, Mg, **Mn**, Mo, Na, **Ni**, P, **Pb**, S, Sb, Sc, Se, Sr, Te, Th, Ti, TI, U, V, W in **Zn**), od katerih 10 (v okvirjih) spada med pogoste TK, ki onesnažujejo tla. Primerjava koncentracij TK v vrtnih tleh z dobro poznanim bogatim naravnim geokemičnem ozadjem območja je pokazala, da so vrednosti vseh primerjanih kovin, z izjemo Al, Fe, Ga, Sc, Th in Co, višje od elementov naravnega ozadja Vzhodnih Alp in celotne Slovenije. Koncentracije TK v tleh vrtov so znotraj ali tik nad vrednostmi naravnega ozadja *[1]*, vendar pod MIV, z izjemo Pb in Zn v štirih vrtovih, kjer koncentracije presegajo OIV *[6]*. Tla vrtov vasi Legen so bila antropogeno obogatena, najverjetneje z vnosom gnojil ter v enem primeru netestiranih in onesnaženih tal od drugod. Za večino vrtov velja, da so ekstremno preskrbljeni s hraniloma P in K; tla so zmerno obogatena z organsko snovjo in imajo povprečno kislost s pH vrednostjo 6.7, kar pomeni, da so tla nevtralna.

1 INTRODUCTION

1.1 Soil Structure

Soil is logically formed natural body composed of mineral particles and organic matter, soil water (i.e., the liquid phase) and air (soil atmosphere), microorganisms and nutrients. They are made up of soil horizons or layers, which are, according to Jenny *[17]*, formed by pedogenetic factors such as parent material, time, climate, topography, living organisms and mankind. A soil profile is defined by a sequence of horizons, more or less with the soil's surface, that differ in various morphological, chemical, physical and biotical properties such as soil structure, texture, acidity, porosity, nutrients and colour. Soil horizons are identified by the excavating a soil profile, a morphological description, chemical and physical measurements of the soil's parameters. *[7]*

1.2 Heavy metals and their sources in soil

Heavy metals (HM) are a persistent type of pollutant. HM not only degrade the quality of the air, water bodies, soils and food crops, but also threaten the health and well-being of animals and humans. Metals accumulate in the tissues of living organisms, because, unlike most organic compounds, they do not undergo metabolic degradation *[8].* HM are responsible for a wide range of human problems due to their toxic effects, including heart disease, cancer, mental health problems, chronic nausea, damage to the kidneys, nervous system and brain, and others. The most important aspect of the ecosystem is the soil which is contaminated heavily with HM. Compared to other pollutants, HM persist longer in soils because they bind to soil particles, from where they are released into the soil solution to become available to plant roots *[9].*

1.2.1 Parent Material

The parent material (PM) is a natural and primary source of HM in the soil. These occur naturally in low concentrations in soils, as their content depends on the parent rock, and its influence on the HM content becomes less pronounced with soil age due to weathering *[10].* In soils formed on PM rich in HM, the soil is, at least in the young development stage, logically rich in HM as well.

1.2.2 Anthropogenic immissions of HM

The main anthropogenic sources of HM are mine tailings, industrial sites, waste deposits with high metal content and leaded gasoline, which was used in the past to fuel vehicles. The combustion of leaded petrol in the engine produces toxic lead compounds which are released into the atmosphere and soil, where they accumulate. Excessive use of organic and mineral fertilizers can also be a source of HM in the soil *[10]*. Various pesticides, irrigation of soils with HM-rich wastewater, sewage sludge and petrochemical substances spillages, contribute to the increased HM content of soils. Heavy metals often enter the soil mainly through atmospheric depositions from various anthropogenic sources *[8].*

1.3 Garden Soils

Garden soils are classified as anthropogenic soils, meaning they have been altered fundamentally by tillage, and can be quite different from natural soils. Garden soils differ from natural or other agricultural soils in being supplied better with nutrients and soil organic matter (SOM), and often containing additives such as ash and/or compost. Their horizons also differ. The top horizon of garden soils is usually deeper and more nutrient-rich, and contains significantly more organic matter than comparable natural or modified soils intended for other agricultural uses. The top horizons are, therefore, deep, usually very loose and porous, as a result of frequent tillage. The pronounced use of organic fertilizers, the most common of which is compost, and sometimes farm manure, has contributed to the increase in SOM content. The addition of mineral fertilizers and occasional application of lime has the effect of reducing soil acidity, and, in the case of excessive doses of fertilizers, of increasing the amount of nutrients to a much greater extent than the plants need at all. The optimum garden soils are humic, loose and crumbly, with a lumpy texture, acidic and supplied adequately with nutrients. Good garden soils should contain approximately 20 mg of phosphorus (expressed as P_2O_5), between 20 and 25 mg of potassium (expressed as K_2O) per 100 g of dry soil, have the acidity of between pH 6 and pH 7 (mildly acidic), contain around 4 to 8% of SOM and be free from contaminants. If the nutrients in the soil are insufficient, they should be added by fertilization. *[11]*

Table 1: *Soil classification based on potassium and phosphorus soil content*

Nutrient content class	Phosphorous content (P_2O_5) (mg / 100 g)	Potassium content (K_2O) (mg / 100 g)
Class A – Poorly supplied	< 6	< 10
Class B – Medium supplied	6 – 12	10 – 19
Class C – Optimally supplied	13 – 25	20 – 30
Class D – Excessively supplied	26 – 40	31 – 40
Class E – Oversupplied	> 40	> 40

SOM also plays an important role in maintaining soil fertility, by retaining and providing nutrients and food for microorganisms, improving the soil's physical and chemical properties, improving soil porosity, and, thus, aeration, retaining soil moisture and binding nutrients to prevent leaching *[12].*

Table2: *Soil classification according to SOM content (%)*

Class	SOM content (%)
Mineral soil	< 1
Poorly humic soil	1 – 2
Medium humic soil	2 – 4
Humic soil	4 – 10
Extremely humic soil	> 10

1.4 Accessibility of HM and measures for safer vegetable production

The accessibility of HM is influenced by the clay and humus content and the acidity of the soil. If the soil is acidic (pH < 5.5), HM are more easily released into the soil solution, and thus become available to the roots. Therefore, care should be taken to maintain soil acidity above pH 6.5. This can be done by adding lime, fine limestone dust, or Ca-rich fertilizers. Clay and humus particles bind HM strongly, immobilizing them, and thus reducing their availability to roots. A good phosphorus supply in the soil helps to retain some forms of HM. Not all plants have the same capability to take up HM from the soil. HM are distributed differently in various parts of the plant. In general, more HM accumulate in leaves and roots than in fruits or seeds. Thus, eating leafy vegetables (spinach and lettuce) and root vegetables (carrots, potatoes and onions) grown in contaminated soil exposes us to more HM than fruit vegetables (tomatoes, peppers and beans). An important aspect of HM is urban composting, as dust particles rich in HM can settle on grass, leaves and green cuttings. Grasses and vegetables on contaminated soils consequently take up some HM from the soil. By composting such leafy materials, we concentrate the HM in the composts, and, later, by applying them, also in the soil of the gardens. *[11]*

1.5 Main features of the study area

The Municipality of Slovenj Gradec can be classified under the Eastern Alps region, as it lies on the border of the Eastern Karavanke mountains, the Pohorje mountains and the Strojna mountains *[1].* In Slovenj Gradec, districts are dominated by dystric cambisols, which make up about half of the Municipality. In the western part there are rendzic leptosols soils on dolomite/limestone and chromic cambisols on limestone. The eutric cambisols soils are found along the river that runs through the municipality. There is also a strip of luvisols *[13].*

1.6 Slovenian Legislation

The Government of the Republic of Slovenia has adopted the Environmental Protection Act (EPA; Official Journal RS, 32/93, followed by the Official Journals RS, 41/04 and 39/06), which contain general measures and basic methods for the protection of the environment and the use of natural resources. According to the EPA, Slovenia is obliged to carry out monitoring of the state of the environment (environmental monitoring) *[14].*

Various laws in the field of Soil Protection have been adopted on the basis of the EPA *[14]*:

- Regulation on the Limit, Warning and Critical Immission Values of Hazardous Substances in the Soil (Official Journal RS, nrs. 68/96, 41/04 – EPA-1 and 44/22 – EPA-2),
- Regulation on the soil pollution by the introduction of waste (Official Journal RS, nrs. 34/08, 61/11 and 44/22 – EPA-2); and
- Resolution on the National Environmental Protection Program for the period 2020-2030 (Official Journal RS, nrs. 31/20 and 44/22 – EPA-2).

Soil contamination is determined according to the Regulation on limit, alert and critical immission levels of substances in soil *[18]*:

"The limit immission value (LIV) is the level of a particular hazardous substance in soil at which the living conditions for plants and animals are ensured, and soil fertility and groundwater quality are not impaired."

"The warning immission value (WIV) is a value at which certain land uses are likely to cause adverse effects or impacts on the environment and human health."

"The critical immission value (CIV) is the level at which contaminated soil is unsuitable for the production of plants for human and animal consumption, and for the retention and filtration of water because of adverse effects and impacts on humans and the environment."

2 MATERIALS AND METHODS

2.1 Garden soil sampling procedure

For the sampling, we selected four small settlements (Legenska village, Krnice, Krnice - Šmartno and the surroundings of Bellevue) in the rural settlement of Legen. Five gardens were sampled in each of them. The sampling was permitted by the garden owners, who were also asked by a questionnaire how often and what kind of fertilizers they used in their gardens. The sampling took place at the end of March 2023. In each garden soil samples were taken over the entire area of the garden, taking five evenly distributed sample increments and homogenizing them into a representative soil sample of the garden. The depth of the sample was kept between 20 and 25 cm and the weight of each increment was approximately 0.5 kg. The soil sampling procedure involved the use of a shovel, which was first inserted perpendicularly into the soil. Another shovel was then inserted from the other end at an angle of 45° and a vertical section of the soil was removed. The homogenized samples were then packed in a plastic bag, which was labeled accordingly for further processing.

2.2 Analytical methods

2.2.1 Laboratory sample preparation

The samples were treated and prepared for further analysis in the laboratory at FEP, Velenje. The samples were placed in a 200 ml beaker, weighing approximately 110 g and shaken carefully to settle and thus remove any major air spaces. The sample beakers are weighed to determine the fresh volume and fresh weight of the samples, which weighed approximately 210 g. We marked the beakers accordingly with the sample codes. The dryer was set to 105 °C, as this temperature is used to obtain absolutely dry soil samples. The samples were placed in the oven for 48 hours. After drying, the samples were crushed and stirred, using a ceramic pestle. Small pebbles and larger roots were removed from the samples with gloved hands. After the pestling, the samples were sieved with a sieve (pore size 0,25 mm) and returned into the marked beakers. The samples were stored in PVC »zip-lock« bags, labeled with the sample serial number. The amount of each sample should be between 30 and 45 g. Before transporting, the samples must be labeled appropriately. The package also needed a Canadian Import Declaration.

2.2.2 Extraction method *Aqua Regia*

Part of the analysis of HM in soil was carried out by Bureau Veritas Commodities, Canada, according to the accredited method ISO 11466:1995 (E). The method used for the analysis was *Aqua Regia* (AQ251) - a solution which is a 3:1 mixture of concentrated HCl (hydrochloric acid) and HNO_3 (nitric (V) acid). In this method, all HM are first extracted from the soil sample by the addition of strong acid, including those that are bound to soil particles very strongly, and therefore unavailable to plants under normal soil conditions. The content of each HM in the extract is then measured using IPC-MS (Inductively Coupled Plasma Spectrometry) analytical equipment to determine the metal content of the soil *[11].*

2.2.3 Analyses at the Agrochemical Laboratory of the Agricultural Institute Slovenia

The other part of the sample analysis was performed in the Agrochemical Laboratory of the Agricultural Institute of Slovenia, located in Ljubljana. The accredited method was used to analyze the pH value of the soil sample in $CaCl_2$ (using ISO 10390:2021) and the content of organic carbon (using SIST ISO 14235:1999 mod.). The plant available phosphorus and potassium (P_2O_5 and K_2O) were analyzed according to the Agrochemical laboratory's internal method *[15].*

3 RESULTS

3.1 Results of the AQ251 analysis

This subsection shows the results of the analysis by the AQ251 method, which were compared with the Regulation on limit, warning and critical immission values for hazardous substances in soil (hereinafter referred to as the Regulation). The results of the comparison of the metals for which the limit and warning immission value was exceeded are additionally shown graphically with the “box-plot” chart.

3.1.1 Cadmium (Cd)

For Cd, the Regulation sets an LIV of ≥ 1 mg/kg, a WIV of ≥ 2 mg/kg and a CIV of ≥ 12 mg/kg. The highest Cd soil content measured was 1.6 mg/kg, while the lowest measured content was 0.3 mg/kg. In 4 out of the 20 sampled garden soils the Cd content was above the LIV, among which the highest measured value exceeded the LIV by 60%.

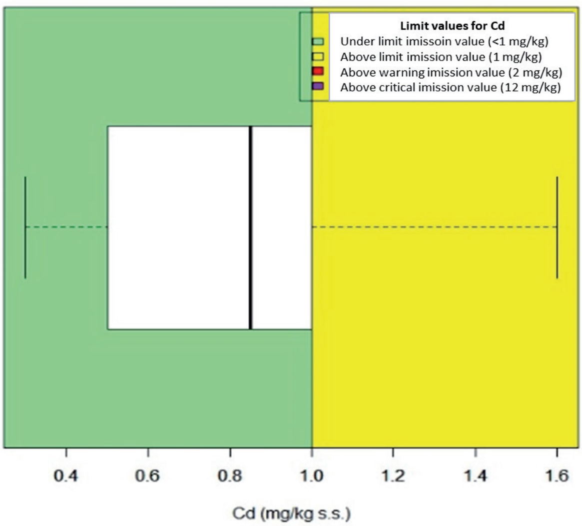


Figure 1: *Cadmium content in the soil of the Legen gardens (mg/kg)*

3.1.2 Zinc (Zn)

For Zn, the Regulation sets an LIV of ≥ 200 mg/kg, a WIV of ≥ 300 mg/kg and a CIV of ≥ 720 mg/kg. The highest measured soil Zn content was 400.0 mg/kg, while the lowest was 112.0 mg/kg. Eight out of the 20 sampled gardens contained Zn above the LIV while, in a further three out of the 20 sampled gardens, the Zn concentrations were above the WIV, with the highest value exceeding the WIV by 33.3%, which means that the soil in these gardens was contaminated.

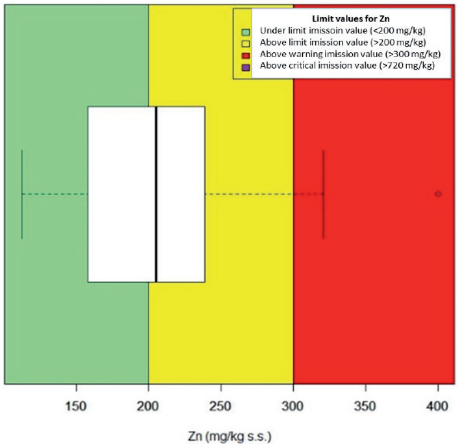


Figure 2: *Zinc content in the soil of the Legen gardens (mg/kg)*

3.1.3 Lead (Pb)

For Pb, the Regulation sets an LIV of ≥ 85 mg/kg, a WIV of ≥ 100 mg/kg and a CIV of ≥ 530 mg/kg. The highest Pb level was 106.6 mg/kg, which is above the WIV by 6.6%, so this particular garden soil was Pb contaminated. In all the remaining sampled gardens the Pb levels were below the LIV, with the lowest level being at 33.4 mg/kg.

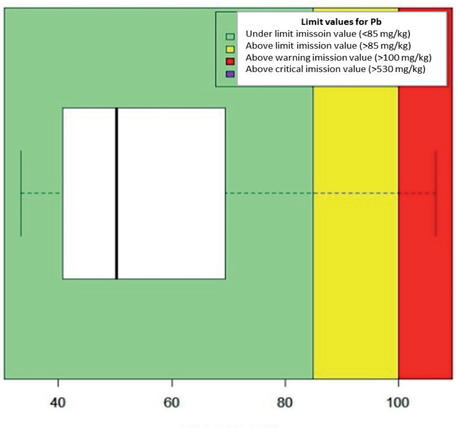


Figure 3: *Lead content in the soil of the Legen gardens (mg/kg)*

3.1.4 Other heavy metals included in the AQ251 analysis

For Arsenic (As), the Regulation sets an LIV of ≥ 20 mg/kg, a WIV of ≥ 30 mg/kg and a CIV of ≥ 55 mg/kg. The As content in the garden soils did not exceed the LIV anywhere. The lowest value measured was 9.5 mg/kg and the highest level was measured at 14.8 mg/kg.

For Cobalt (Co), the Regulation sets an LIV of ≥ 20 mg/kg, a WIV of ≥ 50 mg/kg and a CIV of ≥ 240 mg/kg. The Co content in the garden soils did not exceed the maximum LIV at any location. The lowest content was measured at 10.6 mg/kg, while the highest level was measured at 17.7 mg/kg.

For Chromium (Cr), the Regulation sets an LIV of ≥ 100 mg/kg, a WIV of ≥ 150 mg/kg and a CIV of ≥ 380 mg/kg. The Cr content in the gardens did not exceed the maximum LIV at any point. The lowest Cr content was measured at 31.0 mg/kg, while the highest level was 67.0 mg/kg.

For Copper (Cu), the Regulation sets an LIV of ≥ 60 mg/kg, a WIV of ≥ 100 mg/kg and a CIV of ≥ 300 mg/kg. The Cu content in the sampled gardens did not exceed the LIV at any point. The lowest Cu content was measured at 30.4 mg/kg, while the highest content was 57.2 mg/kg.

For Mercury (Hg), the Regulation sets an LIV of ≥ 0.8 mg/kg, a WIV of ≥ 2 mg/kg and a CIV of ≥ 10 mg/kg. The measured Hg levels in the soil of all the sampled gardens were below the LIV. The lowest content was measured at 0.07 mg/kg, while the highest level was 0.22 mg/kg.

For Molybdenum (Mo), the Regulation sets an LIV of ≥ 10 mg/kg, a WIV of ≥ 40 mg/kg and a CIV of ≥ 200 mg/kg. The measured soil levels of Mo in all the sampled gardens were below the LIV. The lowest levels were measured at 1.1 mg/kg, while the highest level reached 2.8 mg/kg.

For Nickel (Ni), the Regulation sets an LIV of ≥ 50 mg/kg, a WIV of ≥ 70 mg/kg and a CIV of ≥ 210 mg/kg. The Ni content in the soil of the gardens did not exceed the maximum LIV. The lowest Ni content was measured at 25.2 mg/kg, while the highest Ni content was 41.1 mg/kg.

3.2 Standard nutrient analysis

3.2.1 Soil acidity and plant-available potassium and phosphorus content in the garden soil

Soil acidity varied in the sampled gardens and is presented in Figure 4. Ten out of the 20 sampled gardens had neutral soils, i.e., a pH value between 6.8 and 7.2, while the remaining gardens had moderately acidic soils (pH values between 5.6 and 6.7). The average pH value in the sampled gardens was 6.7, presented with the red line in Figure 4. The acidity of the soil in the sampled gardens was generally lower compared with the natural or uncultivated soils of the Legen settlement.

The phosphorus soil content in the sampled gardens is presented in Figure 5. One garden was supplied with medium phosphorus, but otherwise no garden was supplied optimally with phosphorus. The soils of 18 out of the 20 sampled gardens (90%) had an extreme phosphorus oversupply.

In the case of potassium soil content, 50% of the sampled gardens were supplied extremely with potassium. One garden was depleted in potassium, two out of the 20 sampled gardens had a medium potassium content, while five out of the 20 gardens were supplied optimally, and two gardens were oversupplied with potassium. The results are presented in Figure 6.

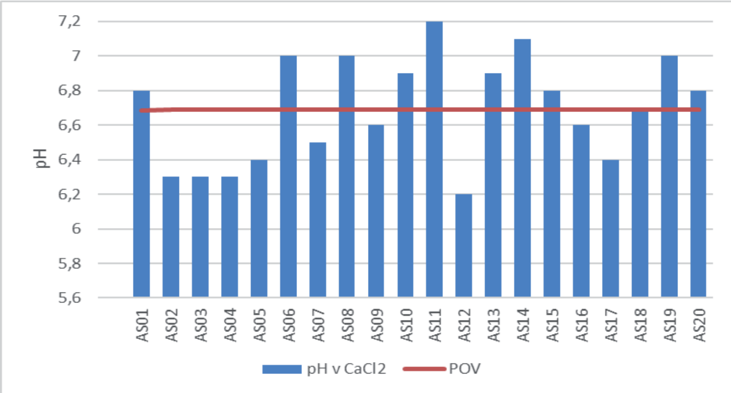


Figure 4: *Soil acidity of the sampled gardens in relation to the measured pH value*

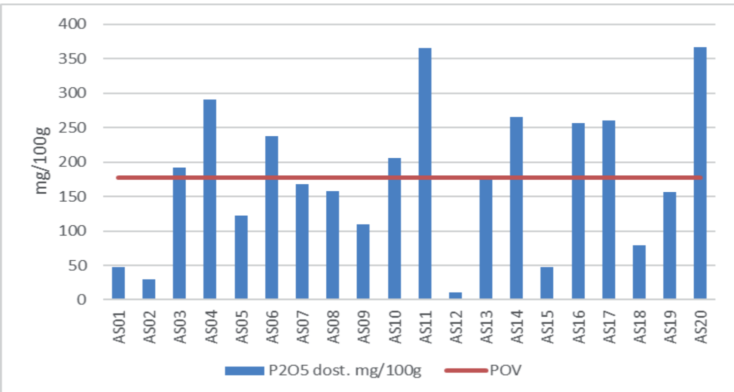


Figure 5: *Plant-available phosphorus concentration in the soil of the sampled gardens*

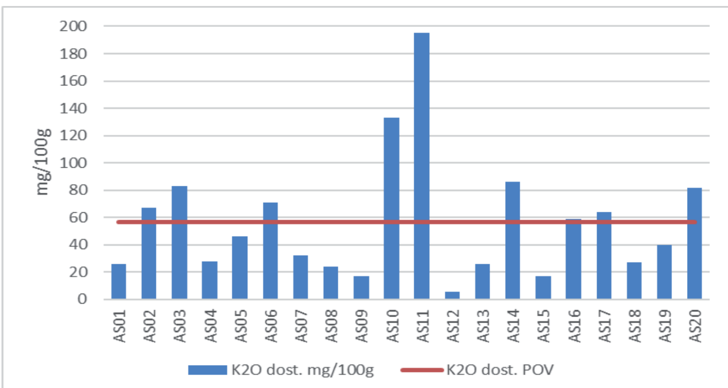


Figure 6: *Plant-available potassium concentration in the soil of the sampled gardens*

3.2.3 Soil organic matter content (SOM)

The total SOM in 5 out of the 20 gardens belonged to the medium-humic soil class, with organic matter below 4 %. 15 out of the 20 gardens (75%) could be ranked to soils rich in SOM. The highest SOM content was measured at 8.68 %. On average, the soil in the gardens in Legen is humic, with an average SOM content of 5.6%, marked with the red line in Figure 7, where the results are presented.

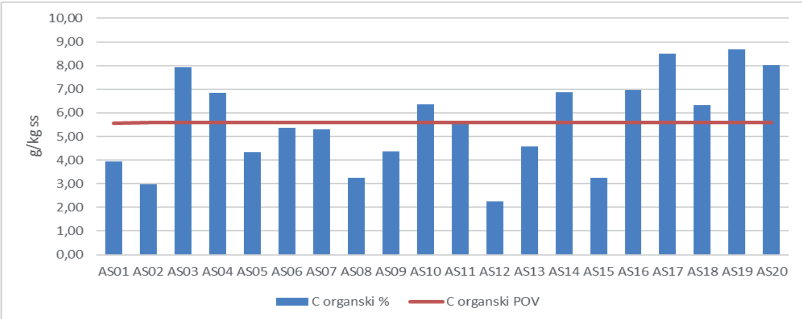


***Figure 7**: Total organic carbon concentration in the soil of the sampled gardens*

3.3 Results of the survey questionnaire

Based on the results of the survey we concluded that in the settlement Legenska village, the owners are generally fertilizing once a year, except for the owners of one garden, who tend to fertilize once every two years. In 60% of the sampled gardens the owners apply manure, in 20% they use homemade compost, and in the remaining 20% they use mineral fertilizers. In this settlement, none of the garden owners used coal ash in their garden, but they used wood ash. In three sampled gardens the owners do not apply any pest and plant weed control products, while insect and other pest control agents were used in two gardens.

Based on the survey, conducted in the settlement Krnice, the owners of the sampled gardens mostly fertilize once a year, apart from one garden, which is fertilized twice a year. In Krnice 40% of garden owners use manure for garden fertilization, 40% of them use horse manure or various briquettes, and the remaining 20% use homemade compost. No one uses coal ash or any other pest or weed control products in the gardens of this settlement.

In Krnice-Šmartno, the owners of the sampled gardens fertilize once a year. The owners use farm manure in 60% of the sampled gardens, homemade compost in 20% and mineral fertilizers in the remaining 20%. The owners of this settlement also use wood ash. With the usage of the questionnaire, we gained the information that untested soil was brought from elsewhere to two of the gardens.

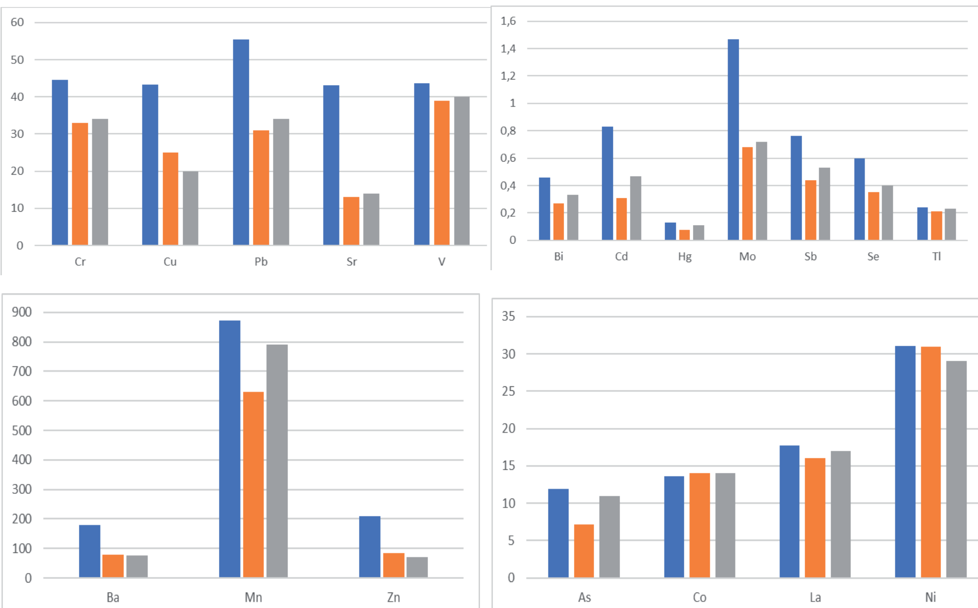
In the Bellevue settlement, the owners of the sampled gardens fertilize once a year. They use farm manure in 60% of the sampled gardens, homemade compost in 20% of the gardens, and mineral fertilizers in the remaining 20% of the gardens. The results of the survey showed that there is no use of coal ash in this settlement. In one of the gardens a plant protection product is used as a pest and plant weed control agent.

4 DISCUSSION

4.1 Comparison of the obtained results with a study on the geochemical background of soils in Slovenia

The HM content in garden soils analysis were compared with the Soil Geochemical Background Survey in Slovenia *[1]* with the median of each HM content in soils of the Eastern Alps and with the median of each HM in soil of the entire Slovenia. We excluded those elements whose measured value was less than 1 µg/kg. The comparison is shown in the combined Figure 9 below.

The results of the comparison showed that the metal contents of Ba, Mn, Zn, Cr, Cu, Pb, Sr, V, Cd, Mo, Sb, Se, B, U and Ca exceed the natural background concentrations for the Eastern Alps, as well as for the overall Slovenia. The contents of the metals Co, La, Ni, Tl, Hg, Bi, Al, Fe and Mg did not show any significant deviation from the other measured values for the Eastern Alps and for Slovenia as a whole. The comparison showed an elevated As content compared to the results for the Eastern Alps. In the case of Ga, the analyzed gardens had higher levels than in the survey for Slovenia as a whole, but lower than the values for the Eastern Alps. Whereas for Sc and Th, the results obtained for the gardens were lower than the Eastern Alps and the total Slovenia results. The elevated Cu levels are most likely due to the use of Cu-based plant protection products and the use of manure, which can contain it. The elevated Pb levels are most likely due to the imported soil to the AS19 garden and the proximity to the traffic corridors, as the Pb levels were higher in Bellevue, which is considered to be a more urban and rather busy settlement. Furthermore, the elevated Cr levels in the garden soils are probably due to the deposition of wood ash obtained by burning wood that has been coated with Cr containing wood preservatives. The Cd, Mo, Sb and Se levels were significantly elevated compared to the Eastern Alps and Slovenia. This is likely due to the use of particular mineral fertilizers and emissions from individual fireplaces in Legen, which should be investigated in future studies.



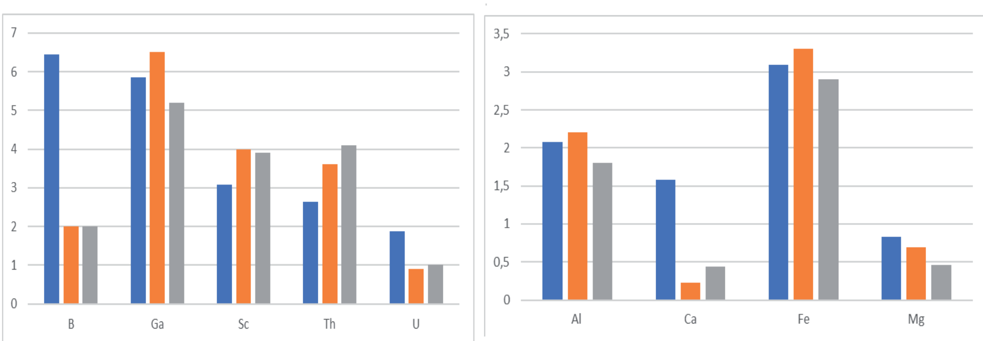


***Figure 8**: Results of the analyzed HM contents (mg/kg) in garden soil (blue column) in comparison with the study for the Eastern Alps (orange column) and total Slovenia (gray column)*

5 CONCLUSIONS

Two HM (Zn and Cd) contents in soil were above the LIV and two HM (Zn and Pb) were above the WIV. Zn was above the LIV in eight out of 20 gardens, with a maximum increase of 39.5%, and exceeded the WIV in three gardens with a maximum increase of 33.3% above the WIV. In the soil of five out of 20 gardens the Cd concentration was measured above the LIV according to the Regulation, with a maximum increase of 60%. Pb exceeded the WIV in one garden soil only, with a maximum increase of 6.6% above the WIV. On the other hand, the LIV for As, Co, Cr, Cu, Hg, Mo and Ni were not exceeded according to the Regulation.

The elevated Pb concentrations in one garden was probably due to newly introduced and untested soil imported from other locations. It is therefore crucial that we ensure that the soil is of good quality and uncontaminated before adding it to our gardens, fields or grasslands. Zn is an important micronutrient for plant growth, so it is added to the soil with various organic fertilizers. It can be assumed that the Zn content could be elevated due to the usage of livestock manure, which contains on average 24.4 g/m^3 Zn. Also, livestock manure could elevate the Cd concentrations in the soils of four gardens. Contributing to the high Zn and Cd content in livestock manure are also the mineral and vitamin supplements fed to animals, Zn coated stable equipment that is prone to excessive corrosion (in the case of Zn), and disinfectants (in the case of Cd). 92-96 % of Zn and 72-80 % of Cd are excreted in animal faeces *[16].*

Comparison with the scientific study on the Natural geochemical background *[1]* shows that, for all the metals included in the comparison, excluding Al, Fe, Ga, Sc, Th and Co, the values in the sampled garden soils were higher than in the Eastern Alps and Slovenia as a whole. This suggests that the owners of the sampled gardens have contributed to the elevated HM concentrations in the soil of their gardens through the use of livestock manure, wood ash and untested soil imported from elsewhere.

The results on the supply of plant-available potassium (K_2O) and phosphorus (P_2O_5) in the gardens showed a predominantly extreme supply, and, according to the classification, most of the gardens can be classified as Class E – heavily oversupplied. The elevated content is due mainly to the addition of fertilizers based on these two nutrients, which are added by the owners for fertilization and to improve soil fertility. We recommend limited use of fertilizers in the gardens sampled, and total non-use, at least for 5 to 10 years, in gardens with extreme stocking rates (Class E).

As an extension of the work, it would be beneficial to analyze garden soils in an additional research of garden soils in the Municipality of Slovenj Gradec, and especially those located in the town center, would contribute additional knowledge and insight of soil quality and therefore the safety of the food produced in vegetable gardens in the area.

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Nomenclature

(Symbols)	(Symbol meaning)
HM	Heavy metals
PM	Parent Material
SOM	Soil Organic Matter
LIV	Limit immission value
WIV	Warning immission value
CIV	Critical immission value
FEP	Faculty of Environmental Protection
EPA	Environmental Protection Act
RS	Republic of Slovenia
Al	Aluminum
As	Arsenic
B	Boron
Ba	Barium
Bi	Bismuth
Ca	Calcium
Cd	Cadmium
Co	Cobalt
Cr	Chromium
Cu	Copper
Fe	Iron
Ga	Gallium
Hg	Mercury
La	Lanthanum
Mg	Magnesium

Mn	Manganese
Mo	Molybdenum
Ni	Nickel
Pb	Lead
Sb	Antimony
Sc	Scandium
Se	Selenium
Sr	Strontium
Th	Thorium
Tl	Thallium
U	Uranium
V	Vanadium
Zn	Zinc