Diplomarbeit

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Influence of soil properties on the accumulation of heavy metals in crops used for baby food production

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I am very grateful to my parents for all of their helps and kindness especially their guidance and encourage about getting more education.

Finally, I am very grateful to all of the people who kindly helped me in this way.

All the best for all of them.

- **Dedication:**

Dedicated to all those who are contributing to development and progression of human knowledge**.**

➢ Table of contents:

➢ Abstract:

To determine the safety limit of different heavy metals in soils (in particular Zn, Cd, Pb) we need to assess the contribution of soil properties on heavy metal bioavailability for crops growing on arable land. Therefore, the aim of this study was under which soil conditions, in particular total and extractable metal concentrations it is safe enough to grow vegetables for baby food productions. Vegetables used for baby food productions require even higher safety standard threshold levels regarding their maximum heavy metal concentrations than normal vegetable productions.

Therefore, the question arises whether production of high-quality vegetables is possible on arable soils with background or slightly elevated metal concentrations. This study was part of two Austrian projects on the survey of metal concentrations in vegetables used for baby food productions and the corresponding availability of heavy metals in arable soils of selected vegetable farms in different areas of Austria.

Through this thesis work, we have found no contamination of heavy metals (Cr, Mn, Ni, Cu, Zn, As, Cd, Pb, Hg) and nitrate in soils and corresponding plant samples.

These results showed that there are no problem for the investigated soils to be used for organic farming and baby food products.

The survey of six different carrot cultivars shows there are indicated different metal uptake and based on the results 3 of them are more recommendable than the others for baby food production

1) Introduction:

1.1) Heavy metals in soils:

Heavy metals in soils are derived from natural components or geological sources as well as from human activities or anthropogenic sources. The residence time of most heavy metals in soil is very long. There are many sources of heavy metals in soils including (Reichman, 2002): Natural e. g. soil parent material, volcanic eruptions, marine aerosols, and forest fires; Agricultural e.g. fertilizers, sewage sludge, pesticides and irrigation water; Energy and fuel production e.g. emissions from power stations; Mining and smelting e.g. tailing, smelting, refining and transportation; Automobiles e.g. combustion of petroleum fuels; Urban/industrial complexes e.g. incineration of wastes and waste disposal; and, Recycling operations e.g. melting of scrap. Vegetables constitute an important part of the human diet since they contain carbohydrates, proteins, as well as vitamins, minerals and trace elements (Awode et al., 2008).

1.2) Plants uptake:

Taken up by plants, heavy metals may enter the food chain in significant amounts. Hence, people could be at risk of adverse health effects from consuming vegetables grown in soils containing elevated metal concentrations. For instance, it is estimated that approximately half of human lead intake is through food, with around half originating from plants (Nasreddine and Parent-Massin, 2002).

Cadmium and lead are the elements of most concern because of their potential for toxicity or accumulation in plants and animals (Wolniketal, 1983). According to the Environmental Protection Agency (EPA), lead is the most common heavy metal contaminant in the environment (Watanabe, 1997) and may be toxic to organisms even when absorbed in small amounts.

Although metals such as zinc, copper and manganese are essential trace elements for plants and animals, they can also be dangerous at high exposure levels. Certain crops such as spinach, lettuce, carrot, radish, Onion can accumulate heavy metals, e.g. Cd, Cu, Mn, Pb and Zn in their tissues (Sauerbeck 1991; Muller and Anke 1994; Hooda 1997; Bahemuka and Mubofu 1999; Cobb et al., 2000; Mattina et al., 2003; Hough et al., 2004; Zhou et al., 2005).

1.3) Metal bioavailability in soils:

Metal bioavailability can be defined as the fraction of the total metal content of the soil that can interact with a biological target (Kidd et al., 2009). In the soil solution elements are present as free uncomplexed ions, ion pairs, ions complexed with organic anions, and ions complexed with organic macromolecules and inorganic colloids.

The most important metal pools in the solid phase include the exchange complex, metals complexed by organic matter, sorbed onto or occluded with in oxides and clay minerals, co-precipitated with secondary pedogenic minerals (e.g. Al, Fe, Mn oxides, carbonates and phosphates, sulphides) or as part of the crystal lattices of primary minerals (Kidd et al., 2009).

Availability to plants is governed by the pseudo-equilibrium between aqueous and solid soil phases, rather than by the total metal content. Based on the consideration of elements being associated with the different geochemical phases of soils there are numerous experimentally defined single and multiple sequential extraction procedures for the elemental speciation analysis (Ure et al., 1993 Tessier et al., 1979).

Since previous research showed that total soil metal content is not generally well correlated with metal mobility and bioavailability. Other soil diagnostic tests including equilibrating the soils with dilute extractants, such as water and neutral electrolyte solutions, or with strong extractants, such as mineral acids or metal-chelating extractants, have been developed to estimate metal phytoavailability (Krishnamurti et al., 1995).

However, the metal concentration found in dilute extractants only represents the concentration of metals in equilibrium with the metals in the solid phase and does not account for the ability of a soil to buffer or replenish the metal in the solution phase. Conversely, strong acid extractants may change the soil conditions considerably and cause soil minerals to dissolve. However, it provides no information of true speciation of elements in soils available in addition to the nonselectivity of extractants used and redistribution of trace elements among geochemical phases during extraction processes (Wang et al., 2001).

1.4) The influence of soil physico-chemical properties:

Plants can strongly influence the bioavailability of metals in soils, e.g. by exuding low molecular organic acids, which can influence the speciation of elements in soil solutions and the uptake of elements by plant roots (Wenzel 2009; Puschenreiter et al., 2001, 2003). The main sources of metals to plants are their growth media (e.g., soil, nutrient solutions) from which metals are taken up by the root (Yan et al., 2007).

Most of the previous studies have shown that increasing concentrations of metals in soil may increase plant uptake. Additionally, the uptake and accumulation of metals in plants are influenced by a number of factors such as availability of metals in soil, plant species, plant age, climate and atmospheric depositions (Junhui et al., 2009). Consequently, the metal availability to plants is quite important when assessing the effect of soil contamination on plant metal uptake (Tokalioglu and Kartal 2003).

The availability of certain metals reportedly depends on the physico-chemical properties of soil such as pH, organic matter (OM) or cation exchange capacity (CEC), redox potential, sulphate, carbonate, hydroxide, soil texture and clay content and on the distribution of metals among various soil fractions (Nan et al., 2002 Junhui et al., 2009). The fraction of heavy metals which can be readily mobilized in the soil environment and taken up by plant roots is considered the bioavailable fraction.

Metal bioavailability varies widely from element to element and according to different plant types. Among the metals, Cd and Zn are fairly mobile and readily absorbed by plants (Mench et al., 1994). In contrast, Cu and Pb are strongly adsorbed onto soil particles reducing their availability to plants (WHO 1998, 1989). In addition, they are bound to organic matter, as well as being adsorbed by carbonate minerals and hydrous iron and manganese oxides.

For example organic matter is known to form strong complexes with heavy metals. The content of organic matter affects speciation of heavy metals in soil (Lo et al., 1992). High organic matter content was reported to decrease concentrations of Cd and Ni in soil solution (Arnesen and Singh, 1999). The plant Cd concentration correlated with OM, EC and CEC. For Zn, the total and residual Zn fractions together with all the selected soil properties mainly explain the Zn concentration in plants, whereas other fractions were poorly related to the Zn accumulation by plants (Junhui et al., 2009).

1.5) Risk assessment of metal contaminated soils:

Elevated levels of metals in soils may lead to increased uptake by plants, however, this depends not only on metal contents in soils but is also determined by other factors such as soil pH, OM, clay content, EC, and phosphate content. Apart from these factors, metal absorption by plants is also significantly influenced by the characteristics of the plants themselves (Hund-Rinke and Kordel 2003).

The success of risk assessment of metal contaminated soils depends on how precisely one can predict the bioavailability of trace and toxic metals in soil and transfer to the human food chain. The use of total concentration as a criterion to assess potential effects of soil contamination is not sufficient, because fate and toxicity of heavy metals in a contaminated soil is greatly controlled by speciation in the soil (Guo et al., 2006) and physco-chemical properties of soil can influence on metal speciation.

Assessing the extent of soil contamination, and the need for intervention, requires the establishment of pollutant threshold values (Kidd et al., 2009). In the case of trace elements, there is only one set of guidance or critical levels that apply to all the countries of the EU, those defined in Annex 1A of Council Directive 86/278/EEC, which establishes limit values (according to soil pH) for concentrations of metals in agricultural soils that should not be exceeded when sewage sludge is applied (Kidd et al., 2009).

In many cases, these critical levels have been extended to soils in general and not only limited to the application of sewage sludge. Many EU Member States are currently developing or updating national strategies for the evaluation and control of contaminated soils (Reimann and Garrett, 2005).

1.6) Safety limits of heavy metals in soils:

To determine the safety limits of different soil heavy metals (especially Zn, Cd, Pb) we need to assess the contribution of soil properties on heavy metal bioavailability in agricultural soils.

Also, vegetables used for baby food productions require even higher safety standards regarding their maximum heavy metal concentrations.

Therefore, the question arises whether production of high-quality vegetables is possible on arable soils with background or slightly elevated metal concentrations.

This study was a part of two Austrian projects on the survey of metal concentrations in vegetables used for baby food productions and the corresponding availability of heavy metals in arable soils of the vegetable farms from different areas of Austria.

2) Research questions:

2.1) What is the correlation between total and labile metal concentrations in arable soil and heavy metal concentration in carrot, onion, potato?

2.2) Is the production of high-quality vegetables possible on arable soils with background or slightly elevated metal concentrations?

2.3) How could the survey of metal concentration in vegetables be used for improving baby food production standards in Austria to determine the higher safety limit of different soil heavy metals (especially Zn, Cd and Pb)?

2.4) What is the difference of heavy metal accumulation in different carrot cultivars used for baby food production in two subsequent years?

3) Aim of study:

3.1) Experiment 1:

The work of experiment 1 was a part of an Austrian project to determine the safety limits of different soil heavy metals (especially Zn, Cd, Pb). The aim of this project was to assess the contribution of soil properties on heavy metal bioavailability in agricultural soils. So in this part of the work we studied soil conditions, in particular total and extractable metal concentrations.

This work was part of a funded research project ("Vegetable minimizing pollutants – heavy metals and nitrates", funded by AGES (Österreichische Agentur für Gesundheit und Ernaehrungssicherheit) Eco-Plus and economical partners, coordinated by Dr. Johannes Balas and Dr. Rita Kappert, Department of Crop Sciences-Institute for Horticultural Sciences-BOKU which aimed to secure the production and processing in organic vegetables (carrot, onion, potato) especially in the bio-premium segment.

These products are subject to special requirements in terms of the limits of contaminants for baby food standards. Even if the cultivation of organic vegetables is well established there are still partly problems with certain heavy metals (particularly mercury, cadmium and lead) and also nitrate in the crops.

3.2) Experiment 2:

The work of experiment 2 was a part of a second Austrian project:

"Comparison and adaptation of open pollinated carrot varieties to drought stress and to the location field in Marchfeld biological farming" (project-funding Ministry for Agriculture, DAFNE and applicant: FiBL Austria, 05/2010-05/2013)

The aim of this research was to determine carrot varieties with lower heavy metal uptake in order to recommend them to farmers producing crops for baby food production.

4) Materials and methods:

4.1) Experiment 1:

In the first part of the project, we obtained soil samples and the corresponding vegetable samples (carrot, onion or potato) from different fields in East Austria.

We measured the total heavy metal concentration in soils after aqua regia digestion whereas other soil parameters such as pH, humus content, P/K/N concentration, clay content and EDTA-extractable metals were determined in a different lab (Agentur für Gesundheit und Ernährungssicherheit AGES, 1220 Vienna, Austria). Additionally, heavy metal concentrations in plants were determined by AGES after acid digestion.

The results were compared with related EU-Laws and national Austrian standard levels such as:

1. Österreichisches Lebensmittelbuch IV. Auflage, Veröffentlicht mit Erlass GZ: BMGFJ-75210/0022-IV/B/7/2008 vom 14.1.2009, Aktionswerte für bestimmte Kontaminanten in Lebensmitteln Codex Unterkommission Schadstoffbelastung bei Lebensmitteln

2. 7. 4. 1999 DE Amtsblatt der Europäischen Gemeinschaften L 91/29, RICHTLINIE 1999/21/EG DER KOMMISSION, vom 25. März 1999, • über diätetische Lebensmittel für besondere medizinische Zwecke , (Text von Bedeutung für den EWR)

3. ENTWURF OeNORM L 1075, Ausgabe: 2004-03-01, Grundlagen fuer die Bewertung der Gehalte ausgewaehlter Elemente in Boeden, (principles for the evaluation of the content of selected elements in soils).

4. COMMISSION REGULATION (EC) No 1881/2006, of 19 December 2006, setting maximum levels for certain contaminants in foodstuffs (Text with EEA relevance) (OJ L 364, 20.12.2006, p. 5)

4.1.1) Soil sampling:

In this experiment, the soil samples were obtained from top soil (0-25 cm) transects across the selected fields. Each sample was a composite of 15 individual probes along the transect.

For soil sampling, we used a stainless steel auger and gathered soil samples from field plots listed in Table 4.1.1 We followed different patterns in direction for example one direction of a cross in small fields and one cross or with extra directions (up to the size) in big fields.

The location of fields, sample codes and crops are shown in Table 4.1.1.

- **Table 4.1.1: Location of the fields, sample codes and crops:**

No.	Code number	Region	Crop kind
1	120	Weinviertel	Potato
2	124	Weinviertel	Potato
3	126	Weinviertel	Potato
4	131	Waldviertel	Onion
5	132	Waldviertel	Onion
6	134	Weinviertel	Onion
7	139	Weinviertel	Onion
8	140	Weinviertel	Onion
9	146	Marchfeld	Onion
10	151	Waldviertel	Potato
11	152	Waldviertel	Potato
12	154	Mostviertel	Potato
13	158	Mostviertel	Potato
14	161	Mostviertel	Potato
15	170	Weinviertel	Carrot
16	101	Marchfeld	Carrot
17	113	Marchfeld	Carrot
18	119	Marchfeld	Carrot
19	108/1	Marchfeld	Carrot
20	108/2	Marchfeld	Carrot
21	109	Weinviertel	Potato
22	110	Weinviertel	Potato

23	111/1	Weinviertel	Potato
24	106	Marchfeld	Carrot
25	162	Weinviertel	Potato
26	169	Weinviertel	Carrot
27	167	Weinviertel	Potato
28	165	Weinviertel	Onion
29	136	Weinviertel	Carrot
30	142	Weinviertel	Potato
31	112	Marchfeld	Carrot
32	101_2	Marchfeld	Carrot

4.1.2) Soil analysis:

Table 4.1.2 provides an overview on the different methods of soil analysis, which were partly carried out by AGES (The Austrian Agency for Health and Food Safety) and partly by BOKU (Universitat fur Bodenkultur-Wien).

- **Table 4.1.2: Soil subjects and measuring methods :**

AGES	BOKU	Subject
		General soil characteristics
✓		pH in $CaCl_2$ ÖNORM L 83
✓		Phosphate in CAL + potassium CAL , ÖNORM 1087
✓		Total N. dry burning elementary analysis ÖNORM 1080
✓		N deliverable: incubation
✓		Grain size Spindle method
		EDTA-extractable metals
✓		Zn, Cu, Fe, MN: EDTA => ICP-OES, ÖNORM L1098
		Total metals
✓		Pb, Cd: Acid digestion (ÖNORM L 1085), Hg: Acid digestion (ÖNORM 1088)
✓		Aqua regia => according ÖNORM L 1085, Cr, Mn, Ni, Cu, Zn, As, Cd, Pb

4.1.3) Assessment of total metal concentrations in soils by aqua-regia digestion:

In the aqua regia method for assessing total metal concentration in soil samples, we weighted 0.5 g of the ground and homogenized dry samples into glass tubes. Then we added the acids using dispensers in the following order: first 4.5 ml of HCl (37%) and then 1.5 ml of HNO_3 (65%).

Then we added one drop of octanol to inhibit foaming (as well to the blanks) and put the coolers on the tubes and left the samples to react overnight at room temperature. The heating was started on the next day. When the digestion heater reached the final temperature (150 ^{o}C), it was left at this temperature for three more hours and rinsed the inner surface of the cooler with distilled water into the tubes and made up their volume to approximately 50 ml.

Then we mixed the samples using a vortex-shaker and took the exact weight of the tubes (including tube + sample + acid + water) and filtered the samples into the appropriate vials to assess total metal (Cr, Mn, Ni, Cu, Zn, As, Cd, Pb) concentrations of the extract liquids via ICP- MS (Perkin Elmer, Elan DRCe 9000).

4.1.4) Plants sampling and digestion:

Gathering the vegetable samples randomly and also digesting plants via acid digestion method was done by AGES (The Austrian Agency for Health and Food Safety AGES, 1220 Vienna). Total N in soils was determined following ÖNORM L 1095.

4.2) Experiment 2:

In experiment 2, the accumulation of As, Cd, Cu, Mn, Pb and Zn in seven different carrot cultivars (S1, S2, S3-1, S3-2, S4, S5, S6) grown in a randomized field plot experiment was evaluated in two subsequent years (Fig. 4.2.1 and 4.2.2). One variety (S3-1, Nantaise 2 Fanal – EliteSG v. Vitalis) was grown only in 2010 whereas another one (S3-2, Nantaise2 Frühbund, H/Mo 14 RFE 402a+b) only in 2011.

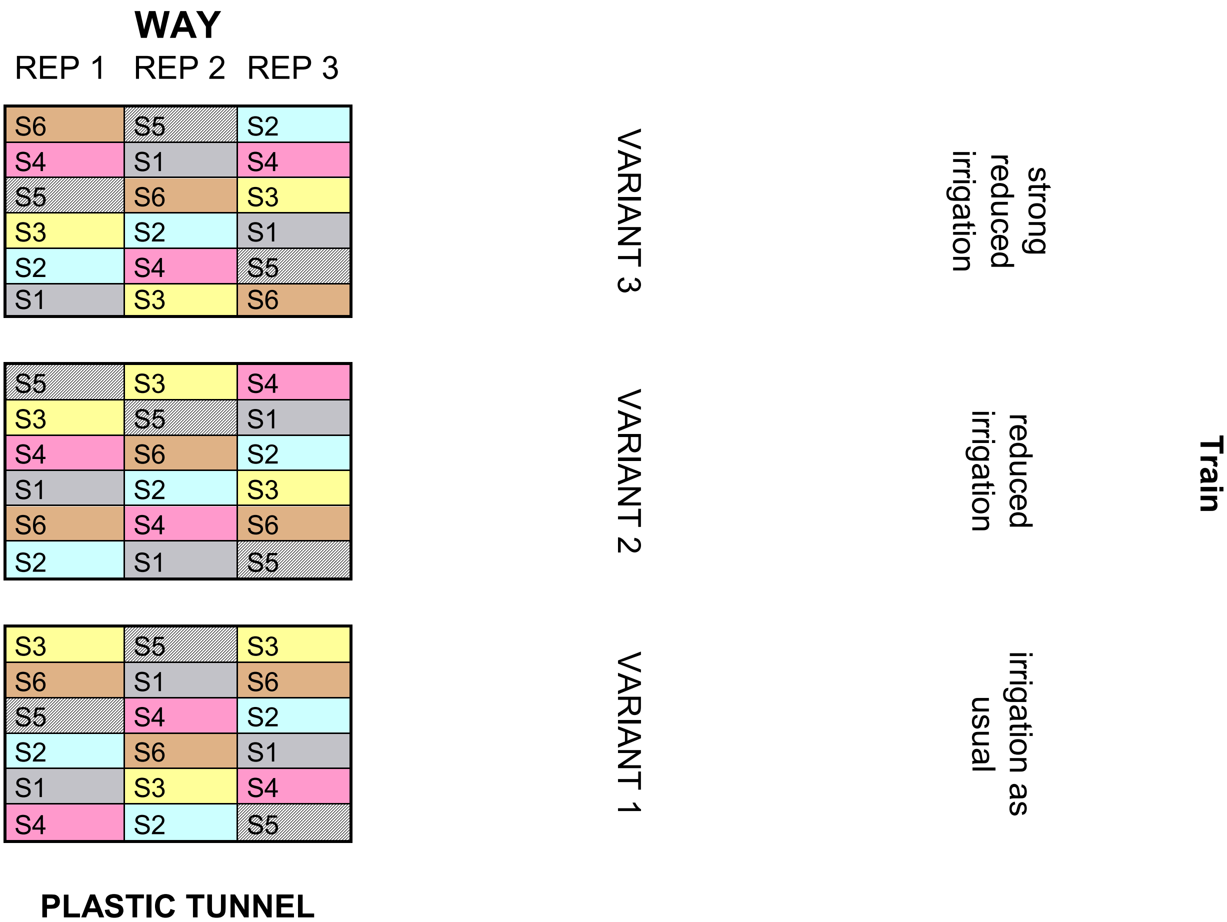
In this experiment, we applied through three different amounts of irrigation (such as usual, reduced and strong reduced irrigation) for the seven different mentioned carrot varieties into the three different variants during the years 2010-11 in the same field (the field address, name and region are showing in Table 4.2.1). The different irrigation treatments were however not considered for data evaluation in this thesis.

The sampling and analytical methods for the determination of nitrate in vegetables are carried out analogously to the Council Regulation (EC) No 1882/2006.

- **Table 4.2.1: Field code number, address, name and region of the second experiment:**

Field Code no.	Field address	Field name	Region
116	2282 Markgrafneusiedl, Glinzendorf 7	An der Bahn /Karottenversuch / 2011	Marchfeld
118	2282 Markgrafneusiedl, Glinzendorf 7	An der Bahn /Karottenversuch/ 2010	Marchfeld

- **Figure 4.2.1: Experimental design for the carrot experiment set up in 2010**



Nr.	**VARIETIES**
S1	Maestro F1
S2	Nantaise 2 Milan
	Nantaise 2 Fanal – EliteSG
S3	v. Vitalis
S4	Nantaise 2 Fynn
S5	Nantes 2 Rotin
S6	Nantaise 2 Beate

- Plot size: 6 x 0,75 m
- Radius sprinkler: 3 m
- Position of sprinkler: 2m
- Distance between plots on the dam: 2 m

➢ **Figure 4.2.2:**
Experimental design for the carrot experiment set up in 2010

WAY

REP 1	REP 2	REP 3	
1-1-6	1-2-5	1-3-2	VARIANT 3 strong reduced
2-1-4	2-2-1	2-3-4	
3-1-5	3-2-6	3-3-3	
4-1-3	4-2-2	4-3-1	
5-1-2	5-2-4	5-3-5	
6-1-1	6-2-3	6-3-6	
7-1-5	7-2-3	7-3-4	VARIANT 2 reduced
8-1-3	8-2-5	8-3-1	
9-1-4	9-2-6	9-3-2	
10-1-1	10-2-2	10-3-3	
11-1-6	11-2-4	11-3-6	
12-1-2	12-2-1	12-3-5	
13-1-3	13-2-5	13-3-3	VARIANT 1 as usual
14-1-6	14-2-1	14-3-6	
15-1-5	15-2-4	15-3-2	
16-1-2	16-2-6	16-3-1	
17-1-1	17-2-3	17-3-4	
18-1-4	18-2-2	18-3-5	

Train

In this table sheet, the numbers are according to the samples. E.G. No. **1-3-2** means:

1 is the row number,
3 is the repetition,

2 is the number of variety, in this case Nantaise 2 Milan

4.2.1) Soils sampling:

Soil sampling and sample preparing for the experiment was done by AGES (The Austrian Agency for Health and Food Safety) for 2010 and by BOKU for 2011.

4.2.2) Soils analyzing:

Soils analyzes have been done with different methods partly by AGES (The Austrian Agency for Health and Food Safety) and partly by BOKU (Universität für Bodenkultur-Wien) based on the methods listed in Table 4.1.2.

4.2.3) Plants sampling:

Plant sampling from the carrot fields was done by AGES (The Austrian Agency for Health and Food Safety) from “2282 Markgrafneusiedl, Glinzendorf 7” –“An der Bahn /Karottenversuch” in Marchfeldand-Austria.

We prepared carrot samples for digesting at BOKU labs of Department of Forest and Soil Sciences, Institute of Soil Science in Tulln.

4.2.4) Plants analyzing:

Carrots digestion has been performed in the Department of Forest and Soil Sciences, Institute of Soil Science in Tulln. 0.2 g dried carrot samples were digested with 5 ml HNO_3 (65%) + 1 ml H_2O_2 (30%). The digested samples were later analyzed for metal concentrations by ICP- MS (Perkin Elmer, Elan DRCe 9000).

4.2.5) TF (Transfer Factor):

The TF (Transfer Factor) is the ratio between plant and total soil metal concentration:

TF = [heavy metal in plant] / [heavy metal in soil]

We calculated TFs for different heavy metals in 7 different carrot varieties during the 2 years (2010-11).

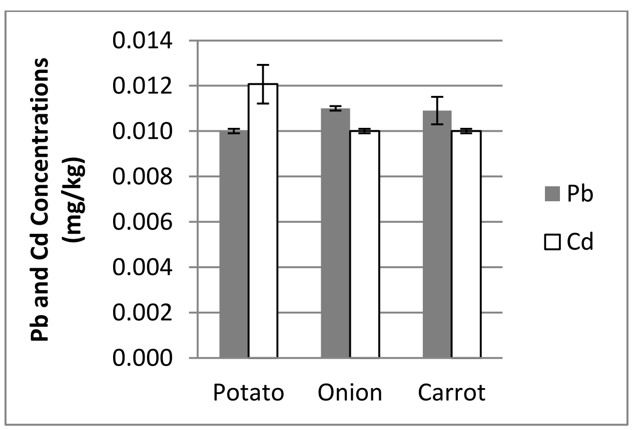
5) Results and Discussion:

5.1) Experiment 1:

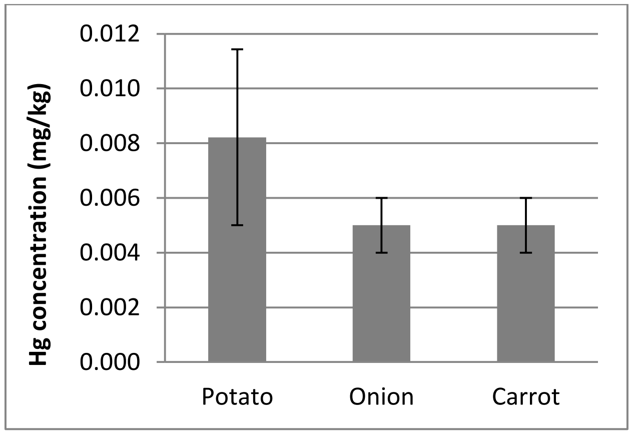
5.1.1) Yield results:

Heavy metal concentrations in plants based on the fresh weights are shown in Figure 5.1.1:

- **Figure 5.1.1: Averages of Pb (gray) and Cd (white) concentrations (mg/kg) in carrots, potatoes and onions. Error bars indicate the standard error of the mean (carrots: n = 11, potatoes: n=14, onions: n=7)**



➢ **Figure 5.1.2: Averages of Hg concentration (mg/kg) in carrots, potatoes and onions. Error bars indicate the standard error of the mean (carrots: n = 11, potatoes: n=14, onions: n=7)**



According to the internal baby food standards-AGES based on the ÖNORM L 1075 (Table 5.1.1), approximate concentrations of trace elements in mature leaf tissue generalized for various species (mg/kg) based on (Table 5.1.2), maximum levels for certain contaminants of heavy metals in foodstuffs (Table 5.2.3) and also (Table 5.1.3) the results indicate that the vegetables (potato, onion and carrot) were taking up heavy metals but the obtained values for carrots, onions and potatoes were relatively low and below the thresholds shown here.
Thus, the crops are acceptable to be used for baby food productions on the investigated field sites.

➢ **Table 5.1.1: Internal baby food standard thresholds for heavy metals (mg/kg, Internal baby food standards- AGES, 2004)**

Internal Baby Food Standard	**Pb FW***	**Cd FW**	**Hg FW**
	0.018	0.018	0.018

***FW**=Fresh Weight

- **Table 5.1.2: Approximate concentrations of trace elements in mature leaf tissue generalized for various species (mg/kg, Kabata-Pendias, 2011)**

Element	Deficient (if less than the stated amounts of essential elements)	Sufficient or normal	Excessive or toxic	Tolerable in agronomic crops
As	-	1-1.7	5-20	0.2
Cd	-	0.05–0.2	5-30	0.05-0.5
Cr	-	0.1–0.5	5-30	2
Cu	2-5	5-30	20-100	5-20
Hg	-	-	1-3	0.2
Mn	10-30	30-300	400-1000	300
Ni	-	0.1-5	10-100	1-10
Pb	-	5-10	30-300	0.5-10
Zn	10-20	27-150	100-400	50-100

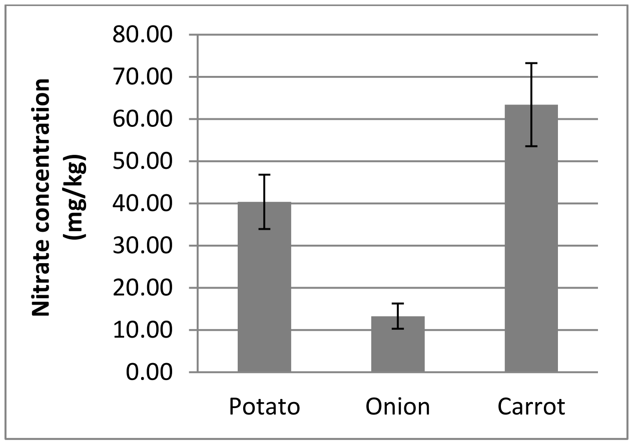
- **Table 5.1.3: Cd concentration in potatoes grown on a highly Cd-contaminated soil (Isermann et al. 1983)**

Crop species	Cd concentration (mg/kg)	Cd concentration (mg/kg)
	mean	**range**
Potato	1.76 (DW)*	1.24–2.48 (DW)

***DW** = dry weight

Nitrate concentrations in the investigated vegetables are shown in Figure 5.1.3:

- **Figure 5.1.3: Nitrate concentration (mg/kg) in carrots, potatoes and onions. Error bars indicate the standard error of the mean (carrots: n = 11, potatoes: n=14, onions: n=7)**



Based on the internal baby food standards – AGES, according to: ÖNORM L 1075 (2004), the standard thresholds level for nitrate uptake in vegetables is **180 mg/kg** (based on the fresh weight) and in soil is **220 mg/kg.**

So, as all of the analyzed vegetables (potato, onion and carrot) had nitrate concentrations below the standard threshold level, we considered all of them being acceptable to be used for baby food productions.

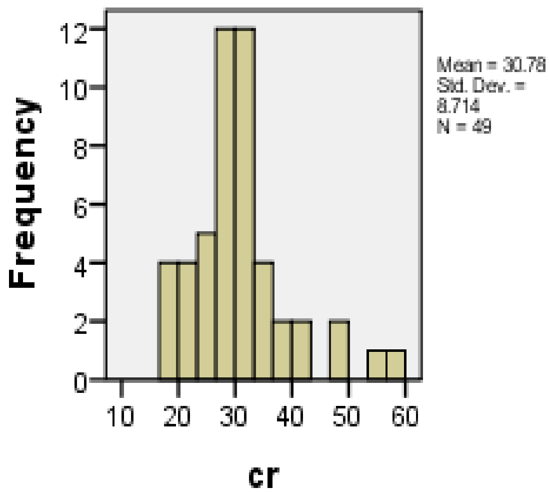
5.1.2) Soil characteristics:

To measure heavy metal concentrations in soils we applied two different methods:

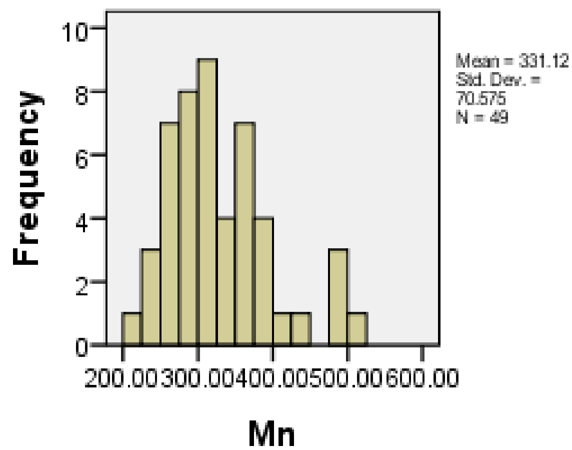
1) Aqua-regia method to measure total concentrations of Pb and Cd
2) EDTA method to measure extractable concentrations of Cu, Zn and Mn

The frequencies of total metal concentrations in soils are shown in Figures 5.1.4 (A-H):

- **Figure 5.1.4 (A-H): Frequency of determined total metal concentrations (mg/kg) in the investigated soils**



A



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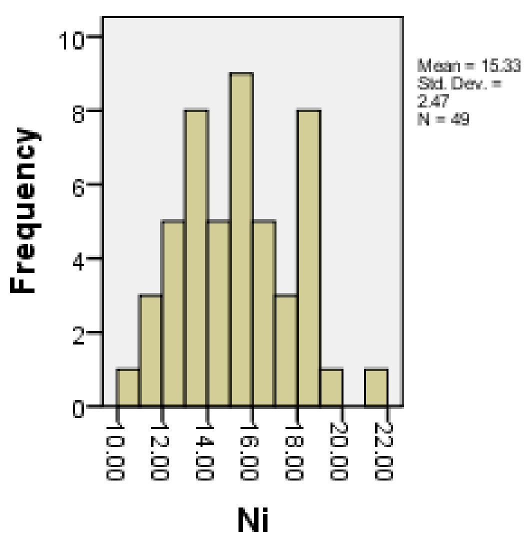
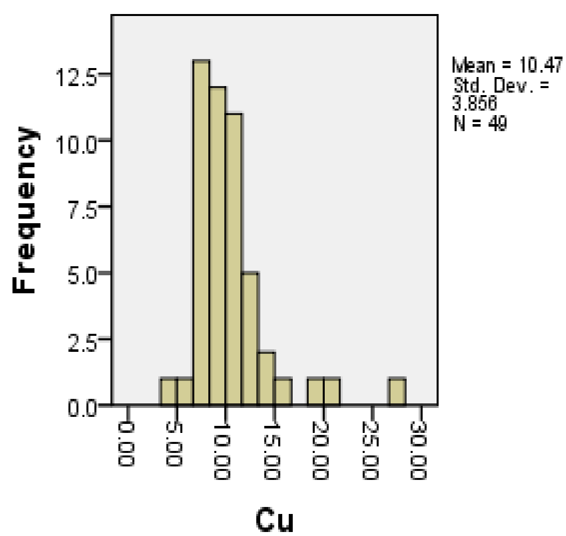
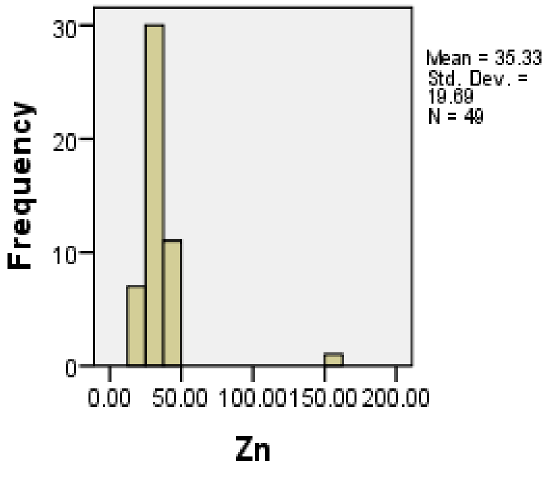


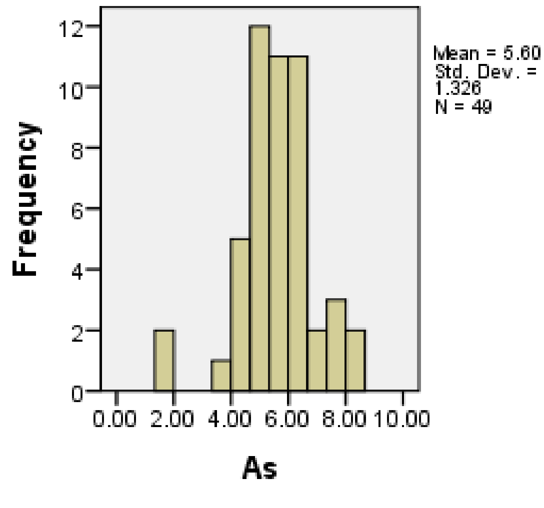
C



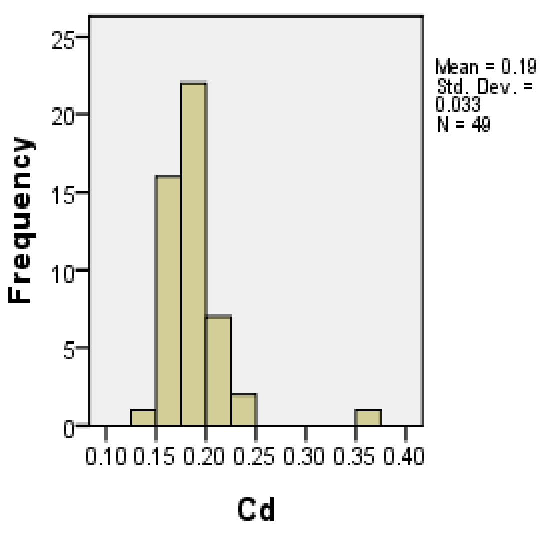
D


Frequency
30
20
10
0
0.00
50.00
100.00
150.00
200.00
Zn
Mean = 35.33
Std. Dev. = 19.69
N = 49

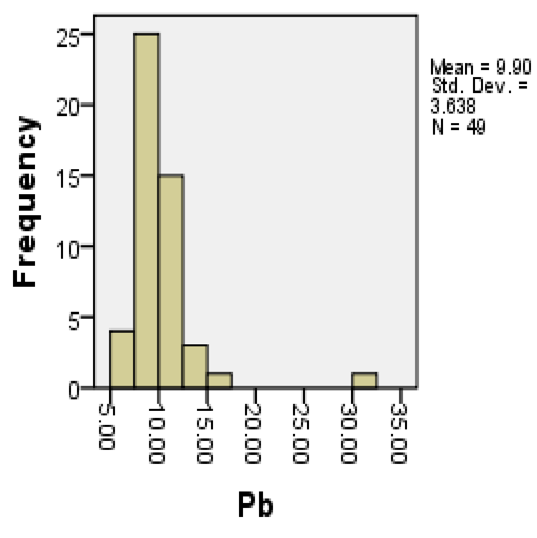
E


Frequency
12
10
8
6
4
2
0
0.00
2.00
4.00
6.00
8.00
10.00
As
Mean = 5.60
Std. Dev. = 1.326
N = 49

F


Frequency
25
20
15
10
5
0
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Cd
Mean = 0.19
Std. Dev. = 0.033
N = 49

G


Frequency
25
20
15
10
5
0
5.00
10.00
15.00
20.00
25.00
30.00
35.00
Pb
Mean = 9.90
Std. Dev. = 3.638
N = 49

H

Based on the Figure 5.1.4 (A-H) the following can be derived:

1) Cr concentrations in soils ranging between 26 and 34 mg/kg were most frequent whereas only a few of them had between 55 and 60 mg/kg.

2) Mn concentrations in soils ranging between 275 and 325 mg/kg were most frequent whereas only a few of them had between 200-225, 400-450 and 500-525 mg/kg.

3) Ni concentrations in soils ranging between 15 and 16 mg/kg were most frequent whereas only a few of them had between 10-11, 19-20 and 21-22 mg/kg.

4) Cu concentrations in soils ranging between 6 and 12 mg/kg were most frequent whereas only a few of them had between 3-7, 15-17 and 18-22 and mg/kg.

5) Zn concentrations in soils ranging between 50 and 75 mg/kg were most frequent whereas only a few of them had between 150 and 175 mg/kg.

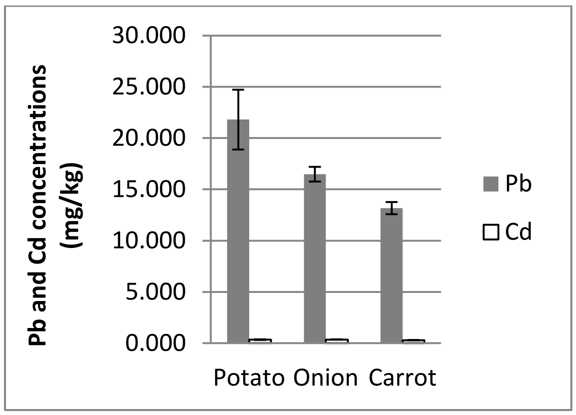
6) As concentrations in soils ranging between 4.75 and 6.75 mg/kg were most frequent whereas only a few of them had between 3.75 and 4 mg/kg.

7) Cd concentrations in soils ranging between 0.15 and 0.20 mg/kg were most frequent whereas only a few of them had between 12.5-15 and 0.35-0.375 mg/kg.

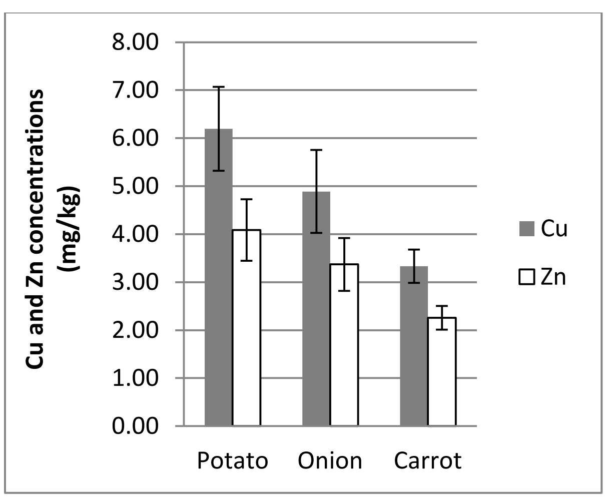
8) Pb concentrations in soils ranging between 7.5 and 10 mg/kg were most frequent whereas only a few of them had between 15-17.5 and 30-33 mg/kg.

Also, the results of average heavy metal concentrations (mg/kg) in the soils where the particular vegetable crops (onion, potato and carrot) were grown are shown in Figure 5.1.5:

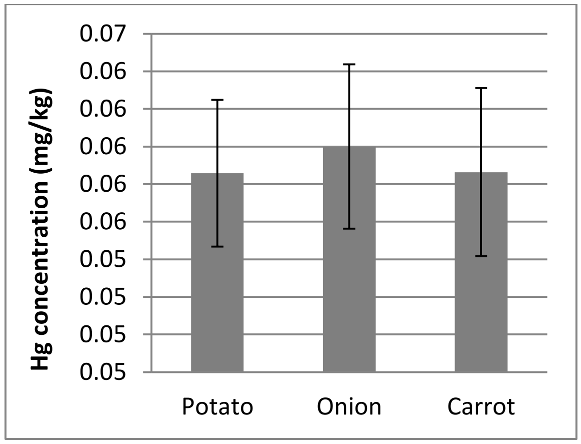
- **Figures 5.1.5: Total heavy metal concentrations (Aqua-regia, mg/kg) for Pb (gray) and Cd (white) in soils of different vegetable fields. Error bars indicate the standard error of the mean (carrots: n = 11, potatoes: n=14, onions: n=7).**



- **5.1.6: EDTA-extractable heavy metal concentrations (mg/kg) for Cu (grey) and Zn (white) in soils of different vegetable fields. Error bars indicate the standard error of the mean (carrots: n = 11, potatoes: n=14, onions: n=7).**



➢ **5.1.7: Hg concentration (mg/kg) in soils of different vegetable fields. Error bars indicate the standard error of the mean (carrots: n = 11, potatoes: n=14, onions: n=7).**



➢ **Table 5.1.4: Cd concentration (mg/kg) in potato grown in a highly Cd-contaminated soil (Isermann et al. 1983)**

Crop species	Cd concentration mean	Cd concentration range
Potato	1.76 DW*	1.24–2.48 DW

***DW** = dry weight

➢ **Table 5.1.5 : Austrian standard threshold levels of heavy metals (FW*, mg/kg) in soils based on pH**

	Cu (EDTA)	Zn (EDTA)	Pb (Aqua-regia)	Cd (Aqua-regia)	Hg
pH < 6	**60**	**150**	**100**	**0.5**	**0.5**
pH > 6	**100**	**300**	**100**	**1.00**	**0.5**

***FW**=Fresh weight

- **Table 5.1.6: Standard threshold levels of heavy metals (mg/kg, aqua-regia) in soils based on pH (mg/kg; Prasad, 2008)**

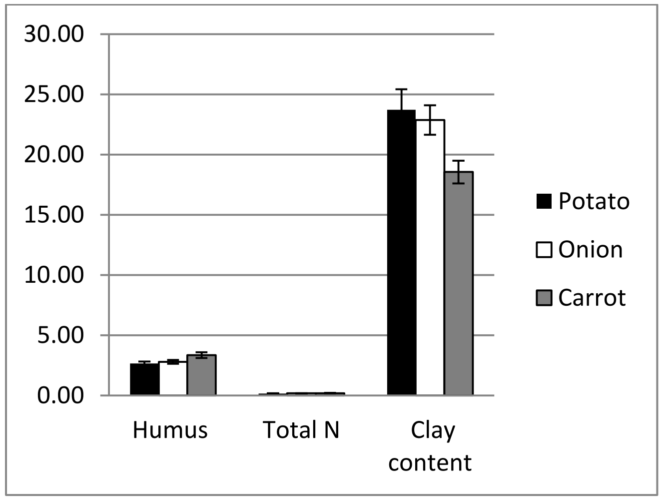
Element	Limit in soils (pH between 6 and 7), DW*
Cd	1-3
Cu	50-140
Pb	50-300
Zn	150-300
Hg	1-1.5
Cr	na*

***DW** =Dry Weight
***na**= Not available

- **Table 5.1.7: Soils physico-chemical characters results. The values represent the average of the sample fields where the respective crops were grown ((carrots: n = 11, potatoes: n=14, onions: n=7).**

Physico-chemical properties of field soils	Potato	Onion	Carrot
CAL-P (mg/kg)	94.14	86.00	74.41
CAL-K (mg/kg)	185.21	184.00	147.32
Total N (%)	0.16	0.17	0.19
available N (mg/kg)	53.50	48.71	40.77
Humus (%)	2.66	2.79	3.35
Clay content (%)	23.71	22.86	18.55
pH	6.99	7.65	7.71
Fe (EDTA) (mg/kg)	227.36	76.43	65.95
Mn (EDTA) (mg/kg)	307.00	193.43	95.82

- **5.1.9: Mass weight percentage (%) of humus, total N and clay in soils of different vegetable fields. Error bars indicate the standard error of the mean (carrots: n = 11, potatoes: n=14, onions: n=7)**



According to the results of the soils in different vegetable fields and based on the reference values shown in Table 5.1.4, Table 5.1.5, Table 5.1.6.; we concluded that the field soils were not contaminated and they are acceptable to be used in organic farming and also for baby food productions.

5.1.3) Metal transfer from soils to plants:

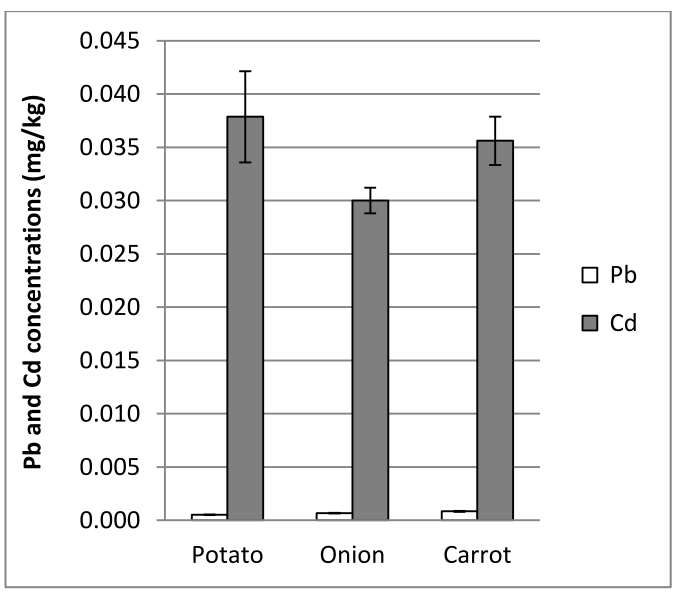
Based on the results for metal concentrations in the investigated crops, we calculated a new set of heavy metal threshold levels (mg/kg) in soils which are recommended to be used with the aim of preventing excessive accumulation of metals in crops used for baby food productions (Table 5.1.8) and to keep the standard levels in organic farming and baby food productions.

➢ **Table 5.1.8: Calculated thresholds for heavy metals (mg/kg) in soils which are planting for baby food vegetable products**

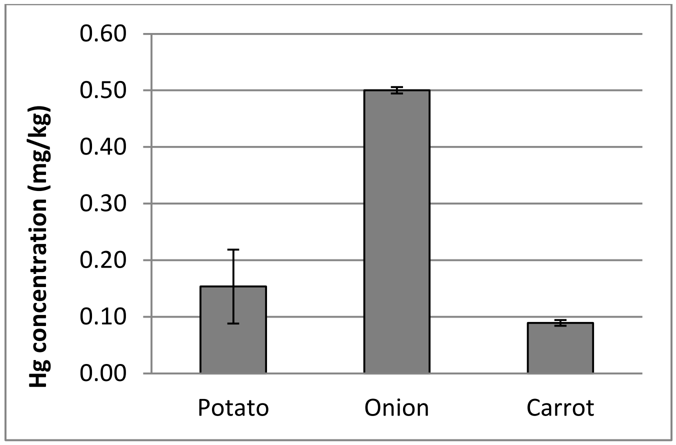
Average	Pb	Cd	Hg
Potato	34.801	0.475	0.065
Onion	26.984	0.600	0.02
Carrot	21.411	0.506	0.112

After determining the heavy metal concentrations in soils and vegetables and comparing them with the standard threshold levels, we calculated TF – Transfer Factors [total concentration in plant (mg/kg) / total concentration in soil (mg/kg)] of heavy metals from soil to the applied vegetables (potato, onion and carrot) based on total soil concentration. The results are shown in the Figures 5.1.10 and 5.1.11:

➢ **Figure 5.1.10: Averages of heavy metal TFs for Cd (gray) and Pb (white) in different plants tissue based on total metal concentrations in soil (carrots: n = 11, potatoes: n=14, onions: n=7)**



➢ **Figure 5.1.11: Averages of Hg TFs in plants tissue (carrots: n = 11, potatoes: n=14, onions: n=7)**



According to comparable literature values shown in Table 5.1.9 , we concluded that the obtained TFs are relatively low, thus the analyzed vegetables (potato, onion and carrot) are not at risk to accumulate significant amounts of heavy metals and are safe to be used as the organic crops and in particular also for baby food productions.

➢ **Table 5.1.9: Transfer factors [total concentration in plant (mg/kg)/total concentration in soil (mg/kg)] of heavy metals from soil to different plant tissues (Machelett et al. 1993; obtained from Puschenreiter et al. 2005)**

	Plant species	**Tissue**	**Cd**	**Cu**	**Ni**	**Pb**	**Zn**
1	**Fodder beet**	leaves	5.55	0.25	0.52	0.07	6.04
2	**Spinach**	leaves	5.00	0.22	0.25	0.13	1.27
3	**Celery**	leaves	2.82	0.15	0.15	0.04	1.22
4	**Celery**	**root**	**2.09**	**0.32**	**0.18**	**0.04**	**0.74**
5	**Lucerne**	shoot	1.73	0.18	0.60	0.02	1.66
6	**Maize**	straw	1.09	0.10	0.06	0.09	1.53
7	**Fodder beet**	**storage roots**	**0.84**	**0.23**	**0.28**	**0.02**	**1.18**
8	**Radish**	**tuber**	**0.50**	**0.10**	**0.15**	**0.02**	**0.72**
9	**Onion**	**tuber**	**0.47**	**0.06**	**0.09**	**0.01**	**0.54**
10	**Tomato**	fruit	0.38	0.18	0.15	0.03	0.21
11	**Potato**	**tuber**	**0.33**	**0.18**	**0.14**	**0.05**	**0.21**
12	**Maize**	cob	0.30	0.11	0.15	0.01	0.68
13	**Winter rye**	grain	0.16	0.12	0.11	0.01	0.61
14	**Bean**	seeds	0.08	0.14	0.28	0.04	0.25

➢ 5.2) Experiment 2:

➢ 5.2.1) Soil results:

Some soil characteristics of the two field plots investigated in experiment 2 are shown in the following table (Table 5.2.1).

➢ **Table 5.2.1: Address and selected soil characteristics of the two investigated field plots in Marchfeld.**

Sample Coding	Address	Field Name	Region	pH	P (mg/kg)	K (mg/kg)	Humus (mg/kg)	Total N (mg/kg)
116	2282 Markgrafneusiedl, Glinzendorf 7	An der Bahn /Karottenversuch 2011	Marchfeld	7.7	136	151	3.3	0.175
118	2282 Markgrafneusiedl, Glinzendorf 7	An der Bahn /Karottenversuch 2010	Marchfeld	7.7	76	82	2.3	0.128

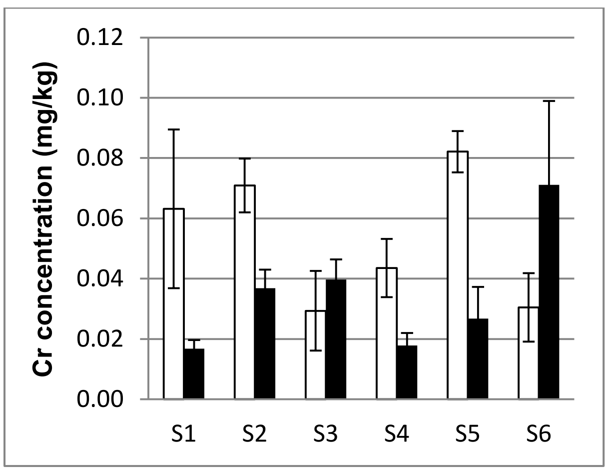
Sample Coding	N available (mg/kg)	Clay content (mg/kg)	Fe(EDTA) (mg/kg)	Mn (EDTA) (mg/kg)	Cu (EDTA) (mg/kg)	Zn (EDTA) (mg/kg)	Pb (Aqua - regia) (mg/kg)	Cd (Aqua-regia) (mg/kg)	Hg (Aqua-regia) (mg/kg)
116	50	22	38	48	4.2	4.5	12.6	0.3	0.06
118	<19	20	25	19	2.5	2	11.1	0.3	0.04

According to Table 5.1.5 and Table 5.1.6, we concluded that all of the heavy metal concentrations (mg/kg) in the soil of both fields were clearly below the standard threshold levels. This suggests that vegetables production in these fields with the aim of organic farming and also for baby food productions is safe.

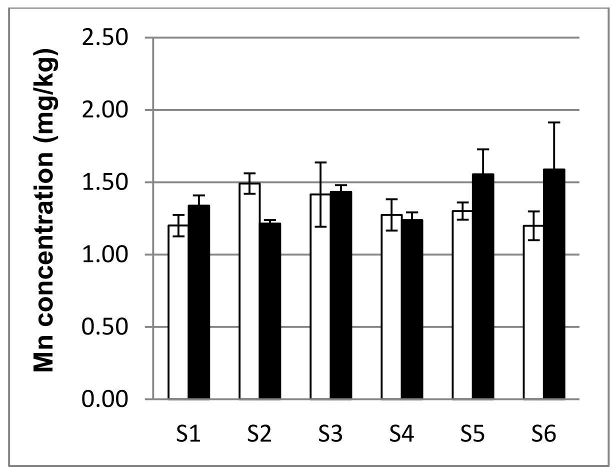
➢ 5.2.2) Metal concentration in carrots:

Based on the obtained results, the next figures (Figure 5.2.1 (A-G) show the averages and standard errors of heavy metal concentrations in 7 different carrot varieties during the 2 years (2010-11) in Marchfeld (2282 Markgrafneusiedl, Glinzendorf 7).

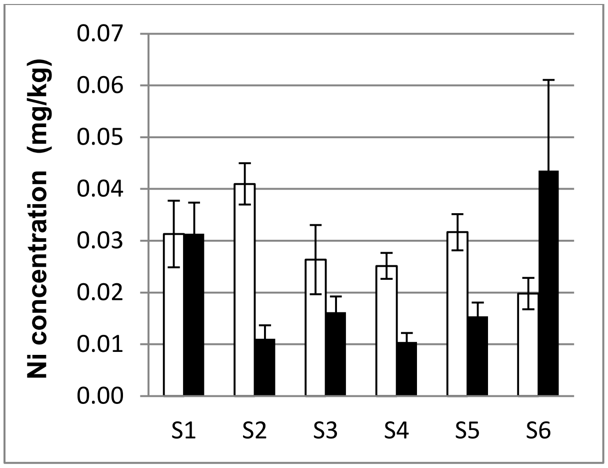
➢ **Figures 5.2.1 (A–G): Averages and standard errors of heavy metal concentrations (mg/kg) in different carrot varieties (S1-S6) during 2 years (2010 in black and 2011 in white) in Marchfeld.**



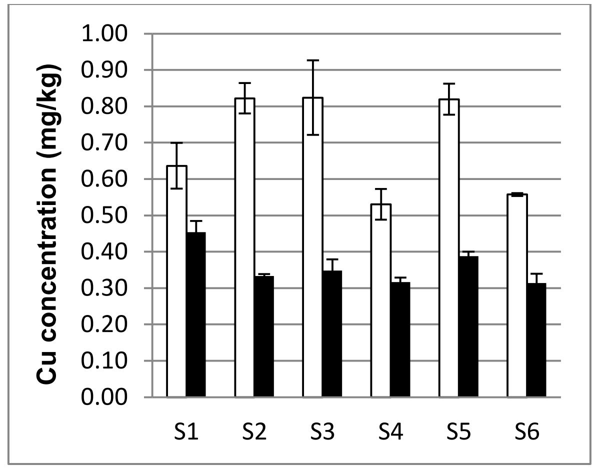
A



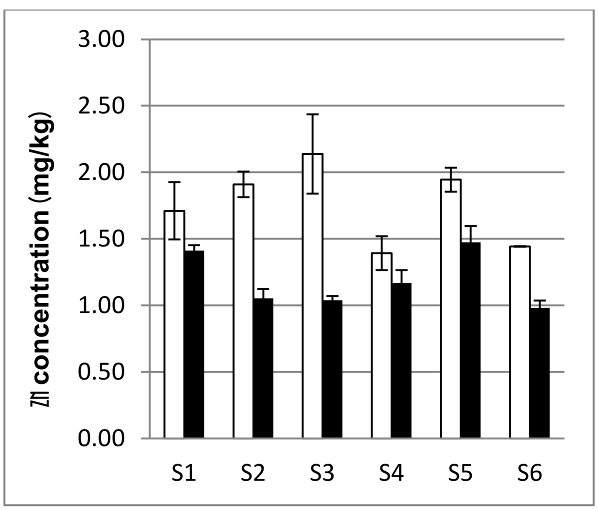
B


Ni concentration (mg/kg)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
S1
S2
S3
S4
S5
S6

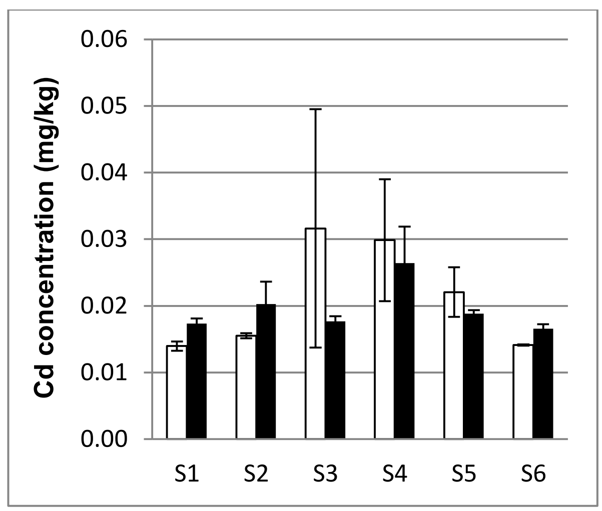
C


Cu concentration (mg/kg)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
S1
S2
S3
S4
S5
S6

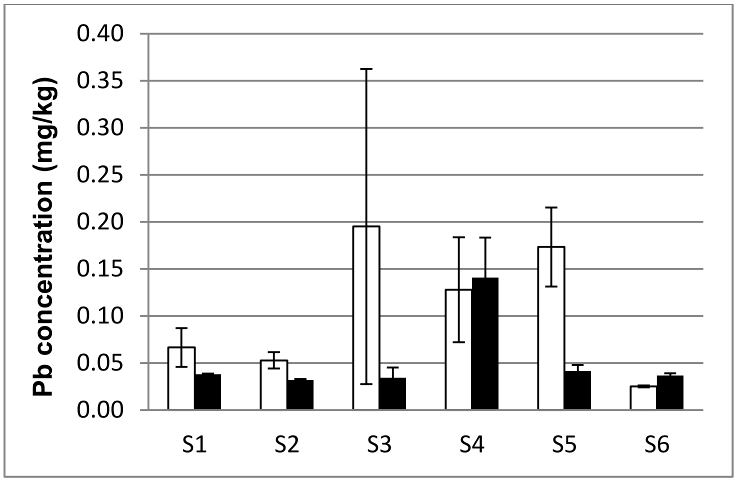
D


concentration (mg/kg)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
S1
S2
S3
S4
S5
S6

E


Cd concentration (mg/kg)
0.06
0.05
0.04
0.03
0.02
0.01
0.00
S1
S2
S3
S4
S5
S6

F



G

➢ **Table 5.2.2 : Maximum levels for certain contaminants of heavy metals in foodstuffs (Alina Kabata-Pendias, 2011)**

Foodstuffs	Maximum levels (mg/kg wet weight)
Lead (Pb)	
Vegetables, excluding brassica vegetables, leaf vegetables, fresh herbs and fungi . **For potatoes the maximum level applies to peeled potatoes**	**0,10**
Brassica vegetables, leaf vegetables and the following fungi (27): Agaricus bisporus (common mushroom), Pleurotus ostreatus (Oyster mushroom), Lentinula edodes (Shiitake mushroom)	0,30
Food supplements (39)	3,0
Cadmium (Cd)	
Vegetables and fruit, excluding leaf vegetables, fresh herbs, fungi, stem	0,050

vegetables, root vegetables and potatoes	
Stem vegetables, **root vegetables and potatoes**, excluding celeriac. **For potatoes the maximum level applies to peeled potatoes.**	**0,10**
Leaf vegetables, fresh herbs, celeriac and the following fungi: Agaricus bisporus (common mushroom), Pleurotus ostreatus (Oystermushroom), Lentinula edodes (Shiitake mushroom)	0,20

Based on the results of heavy metal concentrations (mg/kg) in the crops of different carrot varieties (S1-6) during the 2 years (2010-11) the following can be derived:

With considering heavy metal concentrations (mg/kg, FW*):

1) In Cr plants' uptake results (mg/kg):
   - In 2010: S6 shows the maximum and S1 and S4 show the minimum level of averages and standard errors
   - In 2011: S5 shows the maximum and S3 and S6 show the minimum level of averages and standard errors
2) In Mn plants' uptake results (mg/kg):
   - In 2010: S5 and S6 show the maximum and S2 and S4 show the minimum level of averages and standard errors
   - In 2011: S2 and S3 show the maximum and S1, S4, S5 and S6 show the minimum level of averages and standard errors
3) In Ni plants' uptake results (mg/kg):
   - In 2010: S6 shows the maximum and S2 and S4 show the minimum level of averages and standard errors
   - In 2011: S2 shows the maximum and S6 shows the minimum level of averages and standard errors
4) In Cu plants' uptake results (mg/kg):
   - In 2010: S1 shows the maximum and S4 and S6 show the minimum level of averages and standard errors
   - In 2011: S2, S3 and S5 show the maximum and S4 and S6 show the minimum level of averages and standard errors
5) In Zn plants' uptake results (mg/kg):
   - In 2010: S5 shows the maximum and S2, S3 and S6 show the minimum level of averages and standard errors
   - In 2011: S3 shows the maximum and S4 and S6 show the minimum level of averages and standard errors
6) In Cd plants' uptake results (mg/kg):
   - In 2010: S4 shows the maximum and S1, S3 and S6 show the minimum level of averages and standard errors
   - In 2011: S3 shows the maximum and S1and S6 show the minimum level of averages and standard errors
7) In Pb plants' uptake results (mg/kg):
   - In 2010: S4 shows the maximum and S1, S2, S3, S5 and S6 show the minimum level of averages and standard errors
   - In 2011: S3 shows the maximum and S6 shows the minimum level of averages and standard errors

Thus, the following recommendations are derived:

1) S6: **Recommendable**
- In 2010: Even if it shows maximum plant uptake in Cr, Mn and Ni but in the other investigated heavy metals has minimum uptake.
- In 2011: It shows minimum plant uptake in all of the investigated heavy metals.

2) S5:
- In 2010: It shows maximum in Mn and Zn and minimum in Pb plant uptake.
- In 2011: It shows maximum in Cr and minimum in Mn plant uptake.

3) S4: **Recommendable**
- In 2010: It shows maximum in Cd and Pb and minimum in Cr, Mn, Ni and Cu plant uptake.
- In 2011: It shows minimum in Mn, Cu and Zn plant uptake.

4) S3:
- In 2010: It shows minimum in Zn, Cd and Pb plant uptake.
- In 2011: It shows maximum in Mn, Cu, Zn, Cd and Pb and minimum in Cr plant uptake.

5) S2:
- In 2020: It shows minimum in Mn, Ni, Zn and Pb plant uptake.
- In 2011: It shows maximum in Mn, Ni and Cu plant uptake.

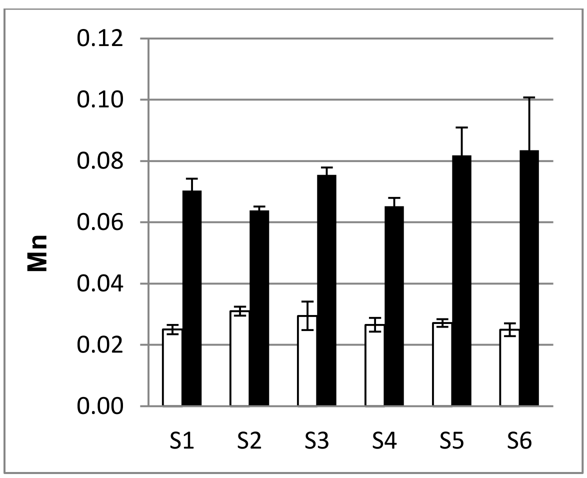
6) S1: **Recommendable**
- In 2010: It shows maximum in Cu and minimum in Cr, Cd and Pb plant uptake.
- In 2011: It shows minimum in Mn and Cd plant uptake.

So, based on the results and according to Table 5.1.1, Table 5.1.2 and Table 5.2.2, we concluded that the three carrot varieties S1, S4 and S6 are recommendable to farmers for planting in case of organic farming and also for baby food productions.

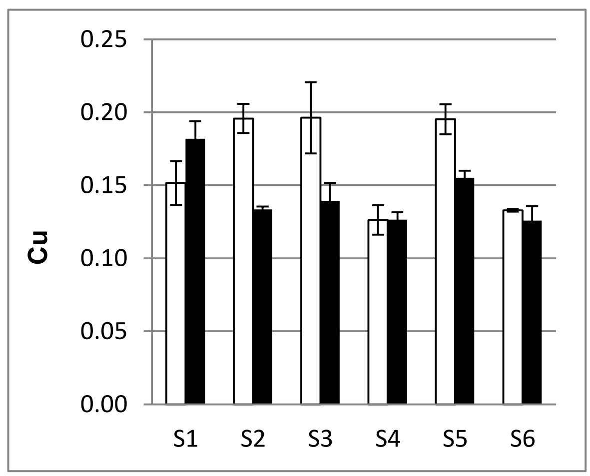
➢ 5.2.3) TFs results:

For the 7 different carrot varieties (S1-S6) during the 2 years (2010-11) and based on the crops and soils results, we have calculated different TFs - transfer factors - for heavy metals based on 2 different metal fractions (EDTA-extractable and total) which are shown in the next Figures.

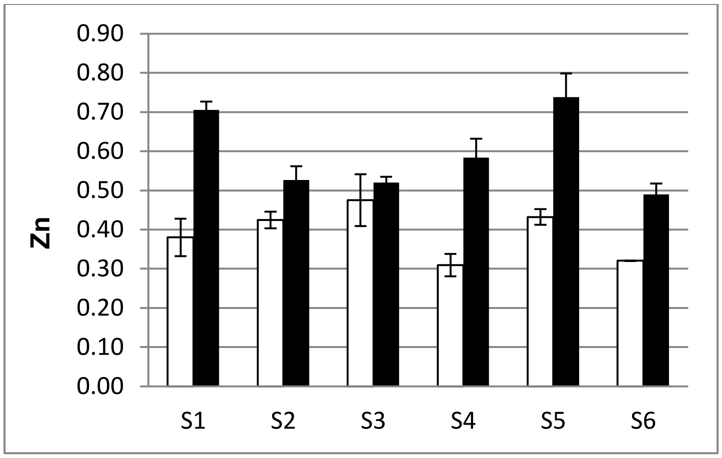
➢ **Figures 5.2.2 (A–C): TF - Transfer Factor – for heavy metals based on EDTA in different carrot varieties (S1-S6) during two years (2010 in black and 2011 in white) in Marchfeld.**



A

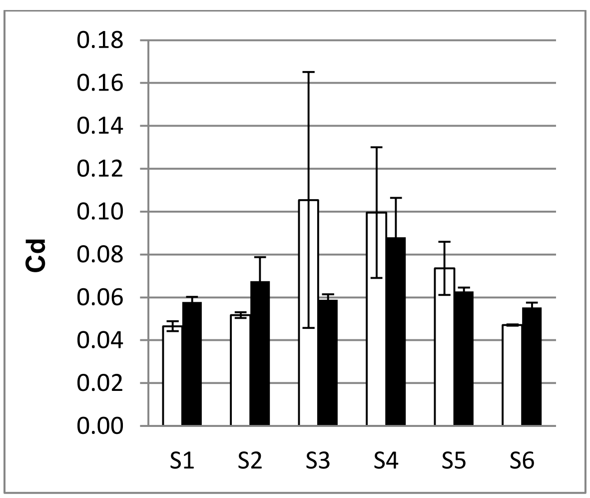


B

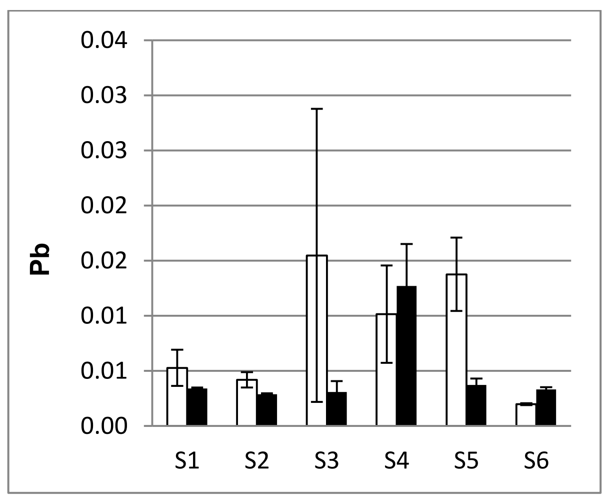


C

➢ **Figures 5.2.3 (A-B): TF- Transfer Factor - for heavy metals based on Aqua-regia in different carrot varieties (S1-S6) during two years (2010 in black and 2011 in white) in Marchfeld.**



A



B

Based on the results of TFs and in compare of the 7 different carrot varieties we explained that:

1) For the EDTA-extractable fraction:

1.1) For Mn:

- In 2010: S2 and S3 had the maximum and S1, S5 and S6 had the minimum transfer.
- In 2011: S6 had the maximum and S2 and S4 had the minimum ratio.

1.2) For Cu:

- In 2010: S1 had the maximum and S2 and S4 had the minimum transfer.
- In 2011: S2, S3 and S5 had the maximum and S4 and S6 had the minimum ratio.

1.3) For Zn:

- In 2010: S1 and S5 had the maximum and S2, S3 and S6 had the minimum transfer.
- In 2011: S3 had the maximum and S4 and S6 had the minimum ratio.

2) In Aqua-regia measuring method:

2.1) For Cd:

- In 2010: S4 had the maximum and S1, S3 and S6 had the minimum transfer.
- In 2011: S3 had the maximum and S1, S2 and S6 had the minimum ratio.

2.2) For Pb:

- In 2010: S4 had the maximum and S1, S2, S3, S5 and S6 had the minimum transfer.
- In 2011: S3 had the maximum and S6 had the minimum ratio.

Regarding the TF results and according to comparative values shown in Table 5.1.9, the presented results indicated that all of the calculated amounts of TFs in 7 different carrot varieties are relatively lower than literature data, so, all of them are acceptable for being used in organic farming and also for baby food productions.

Also, based on the results we derived a set of heavy metals' threshold levels (mg/kg) in soils which are going to be used with the aim of growing the tested carrot cultivars at risk for baby food productions (Tables 5.2.3 and 5.2.4) and to keep the standard levels of organic farming and baby food productions.

- **Table 5.2.3: Calculated thresholds for heavy metals (mg/kg) in soils for safe growth of the tested carrot cultivars and also baby food productions**

Cd (Aqua regia)	S1	S2	S3	S4	S5	S6
Ave. TFs, 2010	0.058	0.067	0.059	0.088	0.063	0.055
Calculated thresholds (mg/kg) in soil, 2010	0.31	0.27	0.31	0.20	0.29	0.33
Ave. TFs, 2011	0.047	0.052	0.105	0.100	0.074	0.047
Calculated thresholds (mg/kg) in soil, 2011	0.39	0.35	0.17	0.18	0.24	0.38

Pb (Aqua regia)	S1	S2	S3	S4	S5	S6
Ave. TFs, 2010	0.003	0.003	0.003	0.013	0.004	0.003
Calculated thresholds (mg/kg) in soil, 2010	5.28	6.25	5.84	1.42	4.82	5.43
Ave. TFs, 2011	0.005	0.004	0.015	0.010	0.014	0.002
Calculated thresholds (mg/kg) in soil, 2011	3.41	4.30	1.16	1.78	1.31	9.04

➢ **Table 5.2.4: Calculated thresholds for heavy metals (mg/kg) in soils for safe growth of the tested carrot cultivars and also baby food productions**

Mn (EDTA)	S1	S2	S3	S4	S5	S6
Ave. TFs, 2010	0.070	0.064	0.075	0.065	0.082	0.084
Calculated thresholds (mg/kg) in soil, 2010	0.26	0.28	0.24	0.28	0.22	0.22
Ave. TFs, 2011	0.025	0.031	0.029	0.027	0.027	0.025
Calculated thresholds (mg/kg) in soil, 2011	0.72	0.58	0.61	0.68	0.66	0.72

Cu (EDTA)	S1	S2	S3	S4	S5	S6
Ave. TFs, 2010	0.182	0.133	0.139	0.127	0.155	0.126
Calculated thresholds (mg/kg) in soil, 2010	0.10	0.13	0.13	0.14	0.12	0.14
Ave. TFs, 2011	0.152	0.196	0.196	0.126	0.195	0.133
Calculated thresholds (mg/kg) in soil, 2011	0.12	0.09	0.09	0.14	0.09	0.14

Zn (EDTA)	S1	S2	S3	S4	S5	S6
Ave. TFs, 2010	0.706	0.526	0.520	0.584	0.738	0.490
Calculated thresholds (mg/kg) in soil, 2010	0.03	0.03	0.03	0.03	0.02	0.04
Ave. TFs, 2011	0.380	0.424	0.475	0.309	0.432	0.321
Calculated thresholds (mg/kg) in soil, 2011	0.05	0.04	0.04	0.06	0.04	0.06

6) Conclusions and Recommendations:

To improve the quality standards with respect to heavy metal concentrations in organic farming and baby food productions in Austria and Europe we carried out a corresponding investigation within two national projects (experiment one and two) with three different vegetables (carrot, onion and potato) during the two years (2010-11) to find out the contaminated level of the field soils and potential risks of significant metal transfer to crops in some regions of Austria.

The results suggest that all of the investigated field soils and their plants have heavy metal concentration levels clearly below the current Austrian and European standard threshold levels. So, none of them were contaminated and all of them could be used in organic farming and also for baby food productions.

Additionally, according to the current European and Austrian standard threshold levels for baby food productions and based on the obtained results from the two experiments we recommend to the farmers to consider the new calculated standard threshold levels for heavy metals in soils up to the Tables 5.1.8, 5.2.3 and 5.2.4.

Finally, based on the second experiment we recommend to the farmers to use vegetable varieties which have the less heavy metal uptakes in compare with the other varieties (such as S6, S4 and S1 as determined in experiment two). In case of other available varieties they should use those which have a lower heavy metal transfer.

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8) Appendix:

1- Table 1.1: Heavy metal concentrations in soil samples of potato fields - experiment 1.

No.	Code number	Region	Crop kind	pH	Cu mg/kg	Zn mg/kg	Pb mg/kg	Cd mg/kg	Hg mg/kg
1	120	Weinviertel	Potato	6.3	3.7	2.5	20	0.4	0.07
2	124	Weinviertel	Potato	7.7	2.9	1.9	13.6	0.3	0.05
3	126	Weinviertel	Potato	7.5	9.8	3	20.8	0.4	0.06
10	151	Waldviertel	Potato	4.8	1.6	2.8	17.3	0.2	0.06
11	152	Waldviertel	Potato	5.9	3.8	6.5	57.7	0.6	0.04
12	154	Mostviertel	Potato	7.2	6.8	4.4	25.5	0.4	0.07
13	158	Mostviertel	Potato	7.4	13.6	8.3	24.7	0.4	0.06
14	161	Mostviertel	Potato	7.5	9.1	9.4	16.4	0.3	0.1
21	109	Weinviertel	Potato	7.1	4.8	4.8	16.3	0.3	0.05
22	110	Weinviertel	Potato	6.6	4.7	2.6	19.4	0.2	0.05
23	111/1	Weinviertel	Potato	7.2	5.3	4	19.6	0.3	0.05
25	162	Weinviertel	Potato	7.6	8.8	2	14.6	0.3	0.05
27	167	Weinviertel	Potato	7.7	4.1	2.1	16.6	0.3	0.05
30	142	Weinviertel	Potato	7.4	7.7	2.9	22.7	0.4	0.06
Average				**6.99**	**6.19**	**4.09**	**21.80**	**0.34**	**0.06**
Max				**7.7**	**13.6**	**9.4**	**57.7**	**0.6**	**0.1**
Min				**4.8**	**1.6**	**1.9**	**13.6**	**0.2**	**0.04**
No. of samples				**14**	**14**	**14**	**14**	**14**	**14**
Median				**7.3**	**5.05**	**2.95**	**19.5**	**0.3**	**0.055**

2- Table 1.2: Heavy metal concentrations in soil samples of onion fields - experiment 1.

No.	Code number	Region	Crop kind	pH	Cu mg/kg	Zn mg/kg	Pb mg/kg	Cd mg/kg	Hg mg/kg
4	131	Waldviertel	Onion	7.6	6.9	4.2	17	0.3	0.07
5	132	Waldviertel	Onion	7.6	7.4	6	16.9	0.3	0.08
6	134	Weinviertel	Onion	7.7	4	3.7	13.8	0.3	0.05
7	139	Weinviertel	Onion	7.7	2.1	2	14	0.3	0.06
8	140	Weinviertel	Onion	7.6	4.5	2.4	17.8	0.4	0.06
9	146	Marchfeld	Onion	7.6	7.1	3.4	18.9	0.3	0.05
28	165	Weinviertel	Onion	7.7	2.2	1.9	17	0.3	0.05
Average				**7.65**	**4.89**	**3.37**	**16.49**	**0.35**	**0.06**
Max				**7.70**	**7.40**	**6.00**	**18.90**	**0.40**	**0.08**
Min				**7.60**	**2.10**	**1.90**	**13.80**	**0.30**	**0.05**
No. of samples				**7**	**7**	**7**	**7**	**7**	**7**
Median				**7.60**	**4.50**	**3.40**	**17.00**	**0.30**	**0.06**

3- Table 1.3: Heavy metal concentrations in soil samples of carrot fields - experiment 1.

No.	Code number	Region	Crop kind	pH	Cu mg/kg	Zn mg/kg	Pb mg/kg	Cd mg/kg	Hg mg/kg
15	170	Weinviertel	Carrot	7.7	3.5	2.7	15.1	0.3	0.05
16	101	Marchfeld	Carrot	7.6	4.9	3.2	13.6	0.3	0.05
17	113	Marchfeld	Carrot	7.6	4.7	2	15.8	0.4	0.06
18	119	Marchfeld	Carrot	7.7	3.6	1.8	13.9	0.3	0.06
19	108/1	Marchfeld	Carrot	7.8	2.1	1	10.7	0.3	0.05
20	108/2	Marchfeld	Carrot	7.8	1.9	1.1	9.6	0.2	0.05
24	106	Marchfeld	Carrot	7.7	2.3	2	12.3	0.3	0.09
26	169	Weinviertel	Carrot	7.9	2.1	1.9	11	0.2	0.05
29	136	Weinviertel	Carrot	7.7	3.4	3	14.1	0.3	0.05
31	112	Marchfeld	Carrot	7.7	3.15	3.5	14.95	0.3	0.085
32	101_2	Marchfeld	Carrot	7.6	5	2.6	13.8	0.3	0.05
Average				**7.71**	**3.33**	**2.25**	**13.17**	**0.29**	**0.06**
Max				**7.90**	**5.00**	**3.50**	**15.80**	**0.40**	**0.09**
Min				**7.60**	**1.90**	**1.00**	**9.60**	**0.20**	**0.05**
No. of samples				**11**	**11**	**11**	**11**	**11**	**11**
Median				**7.70**	**3.40**	**2.00**	**13.80**	**0.30**	**0.05**

4- Table 1.4: Averages of soils heavy metal concentrations in different vegetable fields (mg/kg) - experiment 1.

	Cu mg/kg (EDTA)	Zn mg/kg (EDTA)	Pb mg/kg (Aq.reg.)	Cd mg/kg (Aq.reg.)	Hg (mg/kg)
Potato Average	6.19	4.09	21.80	0.34	0.06
Max	13.60	9.40	57.70	0.60	0.10
Min	1.60	1.90	13.60	0.20	0.04
No. of samples	14.00	14.00	14.00	14.00	14.00
Median	5.05	2.95	19.50	0.30	0.06
Onion Average	4.89	3.37	16.49	0.35	0.06
Max	7.40	6.00	18.90	0.40	0.08
Min	2.10	1.90	13.80	0.30	0.05
No. of samples	7.00	7.00	7.00	7.00	7.00
Median	4.50	3.40	17.00	0.30	0.06
Carrot Average	3.33	2.25	13.17	0.29	0.06
Max	5.00	3.50	15.80	0.40	0.09
Min	1.90	1.00	9.60	0.20	0.05
No. of samples	11.00	11.00	11.00	11.00	11.00
Median	3.40	2.00	13.80	0.30	0.05

5- Table 1.5: Averages of heavy metal concentrations in yields (mg/kg) - experiment 1.

	Pb mg/kg (Aq.reg.)	Cd mg/kg (Aq.reg.)	Hg mg/kg	Nitrate mg/kg
Average Potato	0.01	0.01	0.01	40.34
Max	0.01	0.02	0.05	94.50
Min	0.01	0.01	0.01	2.30
No. of samples	14.00	14.00	14.00	14.00
Median	0.01	0.01	0.01	0.00
Average Onion	0.01	0.01	0.01	13.27
Max	0.02	0.01	0.01	29.70
Min	0.01	0.01	0.01	4.10
No. of samples	7.00	7.00	7.00	7.00
Median	0.01	0.01	0.01	12.30
Average Carrot	0.01	0.01	0.01	63.37
Max	0.02	0.01	0.01	125.29
Min	0.01	0.01	0.01	6.80
No. of samples	11.00	11.00	11.00	11.00
Median	0.01	0.01	0.01	65.80

6- Table 1.6: Averages of TFs for heavy metals in different fields (mg/kg) - experiment 1.

	TF Pb (Aq.reg.)	TF Cd (Aq.reg.)	TF Hg	TF Pb Aq.reg.)
Potato Average	0.00	0.04	0.15	0.00
Max	0.00	0.09	1.00	0.00
Min	0.00	0.03	0.05	0.00
No. of samples	14.00	14.00	14.00	14.00
Median	0.00	0.03	0.09	0.00
Onion Average	0.00	0.03	0.50	0.00
Max	0.00	0.03	0.10	0.00
Min	0.00	0.03	0.06	0.00
No. of samples	7.00	7.00	7.00	7.00
Median	0.00	0.03	0.08	0.00
Carrot Average	0.00	0.04	0.09	0.00
Max	0.00	0.05	0.10	0.00
Min	0.00	0.03	0.06	0.00
No. of samples	11.00	11.00	11.00	11.00
Median	0.00	0.03	0.10	0.00

7- Table 1.7: Averages of physico-chemical aspects of soils in different vegetable fields - experiment 1.

	P mg/kg	K mg/kg	Humus %	Total N%	N available mg / kg	% Clay content	Fe mg/kg	Mn mg/kg (EDTA)	pH
Potato Average	94.14	185.21	2.66	0.16	53.50	23.71	227.36	307.00	6.99
Max	419.00	364.00	3.80	0.21	84.00	34.00	513.00	591.00	7.70
Min	26.00	99.00	1.80	0.12	32.00	10.00	27.00	41.00	4.80
No. of samples	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
Median	70.50	156.50	2.55	0.17	52.00	24.00	233.00	317.50	7.30
Onion Average	86.00	184.00	2.79	0.17	48.71	22.86	76.43	193.43	7.65
Max	120.00	322.00	3.50	0.19	62.00	28.00	149.00	365.00	7.70
Min	53.00	104.00	2.20	0.15	36.00	18.00	23.00	29.00	7.60
No. of samples	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Median	84.00	168.00	2.70	0.17	47.00	24.00	60.00	245.00	7.60
Carrot Average	74.41	147.32	3.35	0.19	40.77	18.55	65.95	95.82	7.71
Max	117.00	239.00	4.80	0.29	59.00	24.00	159.00	246.00	7.90
Min	52.00	67.00	2.20	0.14	32.00	14.00	26.00	32.00	7.60
No. of samples	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
Median	66.00	136.00	3.20	0.18	38.00	18.00	46.00	62.00	7.70

8- Table 2.1: Heavy metal concentrations in different variety of carrot crops - experiment 2.

Set Number	Carrot Samples code name	Cr mg/kg	Mn mg/kg	Ni mg/kg	Cu mg/kg	Zn mg/kg	Cd-1 mg/kg	Pb mg/kg
1	FANAL 2	0.68	14.81	0.29	3.28	11.24	0.16	0.41
2	1.1.6	1.61	27.16	1.04	3.76	11.67	0.19	0.44
3	5.1.2	0.58	12.26	0.19	3.23	8.78	0.14	0.29
4	5.2.4	0.21	12.19	0.07	2.87	7.43	0.14	0.53
5	8.2.5	0.57	12.76	0.10	3.46	12.04	0.18	0.25
6	7.2.3	0.45	13.09	0.09	2.56	9.37	0.15	0.00
8	FANAL 3	0.20	14.92	0.05	3.37	9.58	0.15	0.34
9	14.1.6	0.55	9.51	0.11	3.36	9.24	0.15	0.32
10	9.3.2	0.31	11.35	0.11	3.51	12.90	0.32	0.32
12	17.2.3	0.18	14.17	0.13	4.39	11.10	0.20	0.66
13	15.1.5	-0.06	12.39	0.12	4.14	13.35	0.18	0.38
15	9.2.6.	-0.03	10.94	0.16	2.31	8.49	0.16	0.34
16	15.3.2	0.22	12.81	0.03	3.27	9.91	0.15	0.34
18	3.1.5	0.29	21.52	0.25	4.04	18.87	0.21	0.62
19	FANAL 1	0.45	15.28	0.17	3.63	15.45	0.20	0.44
20	3.3.3	0.57	15.76	0.27	3.50	10.71	0.18	0.37
21	8.3.1	0.12	12.96	0.23	3.53	14.96	0.18	0.35
23	2.3.4	0.39	15.05	0.20	3.87	16.25	0.19	0.36
24	11.2.4	0.01	9.95	0.05	2.78	9.93	0.59	3.94
26	4.3.1	0.27	15.72	0.19	4.81	14.72	0.19	0.40
27	17.3.4	0.10	12.40	0.09	3.13	13.11	0.14	0.80
28	1.3.4	0.22	12.59	0.27	6.44	17.10	0.62	3.21
29	14.2.4	0.32	9.57	0.17	3.94	9.64	0.14	0.26
30	14.1.3	0.25	10.02	0.15	6.22	15.73	0.13	0.29
31	10.3.6	0.53	15.23	0.30	5.49	14.39	0.14	0.28
32	2.3.1	0.14	10.74	0.19	4.99	13.02	0.12	0.28
33	17.1.6	0.47	11.40	0.13	5.53	14.41	0.14	0.26
34	2.1.6	-0.09	9.35	0.16	5.71	14.49	0.14	0.22
35	12.2.3	0.09	17.67	0.27	8.98	22.56	0.67	5.30
36	10.2.6	0.30	11.95	0.39	5.54	15.07	0.17	0.21
37	2.2.1	0.11	11.45	0.52	5.29	12.66	0.15	0.39
38	7.2.1	0.21	10.69	0.21	5.59	13.78	0.14	1.38
39	13.1.5	0.83	14.04	0.38	8.92	22.46	0.16	0.28
40	6.3.3	0.54	14.76	0.38	9.52	25.85	0.14	0.26
41	14.3.2	0.43	15.32	0.29	8.09	20.29	0.15	0.27

42	8.3.5	0.61	14.05	0.19	6.70	17.26	0.35	2.52
43	4.1.5	1.02	10.95	0.38	8.96	18.63	0.15	2.40
44	16.1.1	1.54	14.58	0.54	8.52	24.52	0.16	0.33
45	8.2.4	0.76	16.06	0.31	5.54	15.03	0.14	0.37
46	15.3.4	0.77	12.54	0.37	6.90	16.00	0.16	0.58
47	12.1.2	0.73	12.62	0.41	7.04	15.80	0.17	0.52
48	3.3.2	0.96	16.78	0.53	9.53	21.20	0.15	0.79

9- Table2.2: Averages and standard errors in different carrot varieties (S1-6) during the 2 years (2010-11) in two fields – experiment 2.

	Fresh Carrots	Fresh Carrots	Fresh Carrots	Fresh Carrots	Fresh Carrots	Fresh Carrots	Fresh Carrots
	Cr mg/kg	**Mn mg/kg**	**Ni mg/kg**	**Cu mg/kg**	**Zn mg/kg**	**Cd-1 mg/kg**	**Pb mg/kg**
Average 2011 - S1	0.06	1.20	0.03	0.64	1.71	0.01	0.07
Standard deviation 2011 - S1	0.05	0.13	0.01	0.11	0.37	0.00	0.04
Average 2010 - S1	0.02	1.34	0.03	0.45	1.41	0.02	0.04
Standard deviation 2010 - S1	0.00	0.12	0.01	0.05	0.07	0.00	0.00
Average 2011- S2	0.07	1.49	0.04	0.82	1.91	0.02	0.05
Standard deviation 2011 - S2	0.02	0.12	0.01	0.07	0.17	0.00	0.02
Average 2010 - S2	0.04	1.21	0.01	0.33	1.05	0.02	0.03
Standard deviation 2010 - S2	0.01	0.04	0.00	0.01	0.12	0.01	0.00
Average 2011 - S3	0.03	1.41	0.03	0.82	2.14	0.03	0.19
Standard deviation 2011 - S3	0.02	0.39	0.01	0.18	0.52	0.03	0.29
Average 2010 - S3	0.04	1.43	0.02	0.35	1.04	0.02	0.03
Standard deviation 2010 - S3	0.01	0.08	0.01	0.05	0.05	0.00	0.02
Average 2011 - S4	0.04	1.27	0.03	0.53	1.39	0.03	0.13
Standard deviation 2011 - S4	0.02	0.19	0.00	0.07	0.22	0.02	0.10
Average 2010 - S4	0.02	1.24	0.01	0.32	1.17	0.03	0.14
Standard deviation 2010 - S4	0.01	0.10	0.00	0.02	0.19	0.01	0.08
Average 2011 - S5	0.08	1.30	0.03	0.82	1.94	0.02	0.17

Standard deviation 2011 - S5	0.01	0.10	0.01	0.07	0.16	0.01	0.07
Average 2010 - S5	0.03	1.56	0.02	0.39	1.48	0.02	0.04
Standard deviation 2010 - S5	0.02	0.30	0.00	0.02	0.21	0.00	0.01
Average 2011 - S6	0.03	1.20	0.02	0.56	1.44	0.01	0.03
Standard deviation 2011 - S6	0.02	0.17	0.01	0.01	0.00	0.00	0.00
Average 2010 - S6	0.07	1.59	0.04	0.31	0.98	0.02	0.04
Standard deviation 2010 - S6	0.05	0.57	0.03	0.04	0.10	0.00	0.00

10- Table 2.3: Variable values and variable information for different carrot varieties (S1-S6) – experiment 2.

Variable Values

Value		Label
replicates	**1.00**	s1
	2.00	s2
	3.00	s3
	4.00	s4
	5.00	s5
	6.00	s6

Variable Information

Variable	Position	Label	Measurement Level	Role	Column Width	Alignment	Print Format	Write Format
Variety	1	Cr	Nominal	Input	8	Left	A8	A8
replicates	2	<none>	Nominal	Input	8	Right	F8.2	F8.2
Cr	3	<none>	Scale	Input	8	Right	F8.2	F8.2
Mn	4	<none>	Scale	Input	8	Right	F8.2	F8.2
Ni	5	<none>	Scale	Input	8	Right	F8.2	F8.2
Cu	6	<none>	Scale	Input	8	Right	F8.2	F8.2
Zn	7	<none>	Scale	Input	8	Right	F8.2	F8.2
As	8	<none>	Scale	Input	8	Right	F8.2	F8.2
Cd	9	<none>	Scale	Input	8	Right	F8.2	F8.2
Pb	10	<none>	Scale	Input	8	Right	F8.2	F8.2
VAR00011	11	<none>	Scale	Input	8	Right	F8.2	F8.2
ln_Mn	12	<none>	Scale	Input	8	Right	F8.2	F8.2
ln_Zn	13	<none>	Scale	Input	8	Right	F8.2	F8.2
ln_Cd	14	<none>	Scale	Input	8	Right	F8.2	F8.2
Divition_Cd	15	<none>	Scale	Input	8	Right	F8.2	F8.2
squ_root_Cd	16	<none>	Scale	Input	8	Right	F8.2	F8.2

Variables in the working file

File Information

Source		C:\Users\4161\Documents\Soils elements-Amal-DataSet0.sav
Type		PASW Statistics Data File
Creation Date		26-SEP-2012 17:07:27
Label		None
Character Encoding		windows-1252
File Contents	**Data Type**	Case
	N of Lines of Documents	None
	Variable Sets	None
	Forecasting Date Information	None
	Multiple Response Definitions	None
	Data Entry for Windows Information	None
	TextSmart Information	None
	Modeler Information	None
Data Information	**N of Cases**	49
	N of Defined Variable Elements	19
	N of Named Variables	10
	Weight Variable	None
	Compressed	Yes

Variable Information

Name	Position	Label	Measurement Level	Format	Column Width	Alignment
smplnr	1	<none>	Nominal	A10	10	Left
location	2	<none>	Nominal	A70	70	Left
cr	3	<none>	Nominal	F14	14	Right
Mn	4	<none>	Nominal	F11.2	11	Right
Ni	5	<none>	Nominal	F14.2	14	Right
Cu	6	<none>	Nominal	F11.2	11	Right
Zn	7	<none>	Nominal	F11.2	11	Right
As	8	<none>	Nominal	F11.2	11	Right
Cd	9	<none>	Nominal	F11.2	11	Right
Pb	10	<none>	Nominal	F11.2	11	Right