THE RELATIONSHIP BETWEEN SOME HEAVY METAL CONCENTRATIONS IN SOILS, LEAVES AND FRUITS OF STARKING DELICIOUS (*Malus communis* Lam.) IN VAN, TURKEY

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ABSTRACT

Plants can only live in accordance with the ecologic conditions of their environment. Otherwise they may be unhealthy or die. There is a natural equilibrium between soils, leaves and fruits of plants. If there is soil pollution, it will affect the leaves and fruits of plants. By consuming these leaves and fruits, the health of both animals and humans will be effected negatively and exposed to danger. A simple and sensitive method is described for determination of concentrations of heavy metals in soils, leaves and fruits with flame atomic absorption spectrometry. This method has been applied to the determination of some heavy metal concentrations in soils, leaves and fruits (edible fruit) of Starking delicious, and it found the relationship between metal concentrations in soils, leaves and fruits. For Zn, fruits<soils=leaves; for Pb and Cd, fruits<soils<leaves; for Cr, Ni, Cu, and Co, soils<fruits<leaves; for Se, soils<leaves<fruits; and for Mn, fruits<leaves<soils. Samples were collected from two gardens: the Van

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Agriculture Profession High School (VAPH) and the Van Government Nursery (VGN) in Van City, in East Anatolia, Turkey. Soil samples were dissolved in aqua regia and 20 ml solutions were prepared. A dry-burning method was used on each sample of leaves and fruits and 100 ml solutions prepared. Heavy metal concentrations in samples were investigated by Flame Atomic Absorption Spectrometry (FAAS, Unicam 929).

Keywords: Heavy metals; Soil, leaf and fruit pollution; Uptake of heavy metals by plants.

INTRODUCTION

There have been many studies examining the uptake of heavy metals by plants which show that for a given soil, the rate of metal absorption increases as the concentrations of metals in the soil increase /1/. In soils with a low level of metal contamination, a linear correlation between the concentrations of Cd and Zn in a given soil and Cd and Zn concentrations in plants is frequently observed /2-4/.

There are several mechanisms, which may act concurrently, that could explain the observation that plant uptake of metals increases with increasing soil metal concentration until it reaches a maximum and thereafter is independent of a total concentration of metal in soil. Firstly, in soils which have received inputs of metals as a result of application of fertilizer, there is evidence to suggest that the chemistry of the fertilizer may be important in controlling subsequent metal availability in the soil. Secondly, precipitation reactions could limit metal solubility. Increases in the total metal concentration in the soil above a critical limit for metal precipitation would not lead to further increases in metal concentration in the soil solution, and there would therefore be no further increase in absorption of metals by the plant roots /5,6/.

There are different strategies which could enable plants to tolerate elevated concentrations of metals in the soil. One strategy was the so-called 'excluder' mechanism whereby the plant blocks the translocation of metals from the root to the shoot in order to reduce the accumulation of toxic metals in the leaves. As trace metals such as Zn and Cu are essential micronutrients, any such exclusion mechanism would of necessity either not function or function less efficiently at low concentration of metals in the soil solution, and hence uptake of metals by plants at lower soil concentrations could be concentration dependent. However, when metal concentration in solution reached a threshold level, this mechanism could activate resulting in the concentration-independent uptake of metals that has been reported at higher metal concentrations in the soil /7/.

Another physicological mechanism which could explain these observations is saturation of the system which is responsible for transporting metals into the root. The uptake of Zn and other transition metals is postulated to occur through a channel /8,9/, or carrier mediated process which becomes saturated at relatively low concentrations of substrate in solutions /10,11/.At metal concentrations at which the uptake mechanism is saturated, there would be no further increase in metal uptake with increasing concentrations in the soil solution.

Human activities can irreversibly damage natural resources. Agriculture, urban development, industrialism, and military exercises exert obvious pressures on the quality and quantity of natural resources. Among the many environmental pollutants, trace elements such as lead and cadmium have considerable ecological, biological, and public health significance /12,13/. Although trace elements occur naturally in soil, anthropogenic activities can produce undesirably higher concentrations that may be dispersed through multiple biotic and abiotic processes. The transport, residence time, and fate of pollutants in an ecosystem are serious social concerns. Since the behavior of trace elements in an ecosystem is highly complex, they are usually studied seperately for air, water, soil, and biota /14/.

Plants are good soil quality indicators and respond directly to air quality. Since plants can naturally uptake pollutants from their local environment, their chemical composition can indicate degree of disturbance when assessed against background values obtained from unpolluted vegetation. The significant role of plants in spreading toxic elements has been well illustrated for several ecosystems /15-17/. Plants adapt to great variability of chemical properties in their environment and are intermediate reservoirs through which trace elements in soil, water, or air move to animals and humans /14/. There are several techniques available for the determination of trace elements in soil, leaf, and fruit, including graphite furnace atomic absorption spectrometry (GFAAS), flame atomic absorption spectrometry (FAAS), inductively coupled plasma-mass spectrometry (ICP-MS) , and inductively coupled plasma-atomic emission spectrometry (ICP-AES) /18, 19/.

The purpose of this study was the relationship between heavy metal concentrations in soils and uptake by leaves and fruits of the Starking apple plants.

EXPERIMENTAL

The soils, leaves, and fruits were randomly collected in two Starking delicious gardens (VAPH, VGN) in Van region, at East Anatolia of Turkey. The leaves and fruits were collected from the same Starking delicious and soils under the same plants. Soil samples were dried at 105 °C for 2 h and ground to pass through 200 mesh (0.075 mm) sieve and homogenized for analysis /20/. One g of sieved samples was dissolved in 15 ml aqua regia and each sample was evaporated to dryness on sand bath. The residue was treated with 10 ml 2 M HNO_3 and the suspension was filtered a blue band filtering paper. The filtrate was evaporated to 15-17 ml and then diluted to 20 ml with double-distilled water. All leaf and fruit samples were washed in fresh running water to eliminate dust, dirt, possible parasites or their eggs and then were again washed with double-distilled water and were made in slices /21/, and oven dried at 90 °C for 24 h before grinding /22/, were grinded with porcelain mortar and sieved 200 mesh (0.075 mm). One g of dry matter was weighed in the porcelain crucible, fallowed by the addition of 2 ml mixture of ethyl alcohol and sulphuric acid (95/5, v/v) and burned. After burning, it was ashed at 500-550 °C in a muffle furnace /23/. After that the ash was dissolved with 4 ml 3 N HCl and the solution transferred to 100 ml calibrated flask and diluted to 100 ml with double-distilled water and filtered after 5-6 h with blue band filtering paper and again regulated to 100 ml /24/.

The concentrations of some heavy metals in soils, leaves, and fruits were measured by Flame Atomic Absorption Spectrometry (FAAS, UNICAM 929).

RESULTS AND DISCUSSIONS

The mean values of Zn, Pb, Cd, Cr, Ni, Cu, Co, Se and Mn concentrations in soils, leaves and fruits of the Starking delicious in two gardens (VAPH, VGN) in Van region are given in Tables 1, 2, 3, 4, 5, 6, 7 and Figures 1, 2 and 3.

In soils: The levels of Zn, Cd and Ni obtained from VGN are higher than

Table 1

The concentrations of some heavy metals in soil collected from VAPH apple garden (ppm)

Element	Sample Centres									
	1	2	3	4	5	6	7	8	9	10	Mean and SD*
Zn	16**	15	15	17	19	19	21	18	15	18	17.3±2.0
Pb	74	84	69	69	118	124	109	78	85	102	91.2±20.5
Cd	18	14	22	27	32	23	21	15	20	25	21.7±5.5
Cr	62	52	48	58	47	44	68	49	64	57	54.9±8.1
Ni	76	75	88	107	111	74	101	117	120	73	84.2±31.5
Cu	54	47	46	44	82	51	55	49	42	53	52.3±11.3
Co	45	54	52	48	46	44	56	52	43	57	49.7±5.1
Se	32	25	30	27	34	26	40	27	32	48	32.1±7.2
Mn	528	478	498	368	425	491	348	400	398	420	435.4±60.2

* Standard Deviation

** N=6

Table 2

The concentrations of some heavy metals in leaves of the Starking delicious collected from VAPH apple garden (ppm).

Element	Sample Centres										
	1	2	3	4	5	6	7	8	9	10	Mean and SD*
Zn	38**	25	23	21	21	25	26	37	32	22	27.0±6.4
Pb	188	220	209	185	225	230	211	200	215	195	207.8±15.4
Cd	43	51	41	54	48	54	41	50	49	53	48.4±5.1
Cr	108	128	130	115	110	125	100	119	90	110	113.5±12.6
Ni	150	165	142	202	205	200	190	180	160	165	175.9±22.7
Cu	79	66	50	65	76	98	85	102	96	105	82.2±18.3
Co	140	132	124	120	102	136	163	184	162	182	144.5±27.3
Se	56	45	68	65	74	66	90	85	102	62	71.3±16.9
Mn	152	161	162	157	170	155	172	182	184	165	166.0±10.9

* Standard Deviation

** N=6

Table 3

The concentrations of some heavy metals in fruits of the Starking delicious collected from VAPH apple garden (ppm).

Metals	Sample Centres									
	1	2	3	4	5	6	7	8	9	10	Mean and SD*
Zn	18**	15	17	23	20	26	27	20	26	24	21.6±4.2
Pb	52	47	68	56	74	62	48	52	46	55	56.0±9.3
Cd	11	9	10	7	6	6	5	4	5	6	6.9±2.3
Cr	62	65	80	76	96	66	65	90	85	90	77.5±12.5
Ni	76	74	84	100	98	100	105	99	112	78	92.6±13.4
Cu	57	56	80	78	84	60	64	52	78	92	70.1±13.9
Co	107	102	68	78	82	105	102	113	107	121	98.5±16.8
Se	103	52	48	90	102	50	70	62	80	60	71.7±21.0
Mn	62	70	58	68	54	72	65	61	49	52	61.1±7.8

* Standard Deviation

** N=3

Table 4

The concentrations of some heavy metals in soil collected from VGN apple garden (ppm).

Element	Sample Centres										
	1	2	3	4	5	6	7	8	9	10	Mean and SD*
Zn	28**	25	34	24	33	32	36	28	35	36	31.1±4.5
Pb	103	80	70	105	95	88	70	100	113	105	92.9±15.2
Cd	34	25	38	32	35	27	36	40	41	37	34.5±5.2
Cr	61	45	53	47	40	45	39	44	51	43	46.8±6.6
Ni	87	99	107	112	108	142	96	112	118	123	110.4±15.4
Cu	55	69	68	49	52	45	62	63	50	58	57.1±8.3
Co	46	43	52	69	57	56	61	41	65	47	53.7±9.5
Se	24	29	32	27	30	37	42	23	40	34	31.8±6.5
Mn	375	341	410	442	378	412	346	362	428	370	386.4±34.6

* Standard Deviation

** N=6

Table 5

The concentrations of some heavy metals in leaves of the starking delicious collected from VGN apple garden (ppm)

Element	Sample Centres										
	1	2	3	4	5	6	7	8	9	10	Mean and SD*
Zn	22**	27	26	25	19	18	20	21	16	18	21.2±3.7
Pb	220	184	230	195	240	210	260	235	257	250	228.1±25.7
Cd	44	36	52	54	40	60	45	56	38	48	47.3±8.1
Cr	102	98	135	130	100	110	88	114	90	95	106.2±16.0
Ni	122	88	128	122	96	135	108	120	153	144	121.6±20.2
Cu	136	140	115	145	111	105	135	142	136	108	127.3±15.6
Co	112	116	132	130	146	109	92	82	122	116	115.7±18.8
Se	51	40	44	38	45	64	50	45	42	58	47.7±8.2
Mn	220	208	241	189	185	212	198	182	212	205	205.2±17.8

* Standard Deviation

** N=6

Table 6

The concentrations of some heavy metals in fruits of the Starking delicious collected from VGN apple garden (ppm).

Metals	Sample Centres										
	1	2	3	4	5	6	7	8	9	10	Mean and SD*
Zn	20**	18	27	32	23	18	15	20	28	17	21.8±5.5
Pb	48	52	38	57	74	51	54	62	42	46	52.4±10.3
Cd	11	9	7	9	14	12	15	12	14	13	11.6±2.6
Cr	40	54	80	54	58	56	81	102	85	65	67.5±18.8
Ni	134	124	120	127	130	126	98	127	142	124	125.2±11.4
Cu	83	92	93	85	92	55	72	107	65	76	82.0±15.3
Co	80	98	108	115	102	82	98	125	132	111	105.1±16.8
Se	44	52	54	65	45	70	62	55	62	48	55.7±8.8
Mn	71	55	67	63	78	59	52	61	45	57	60.8±9.6

* Standard Deviation

** N=3

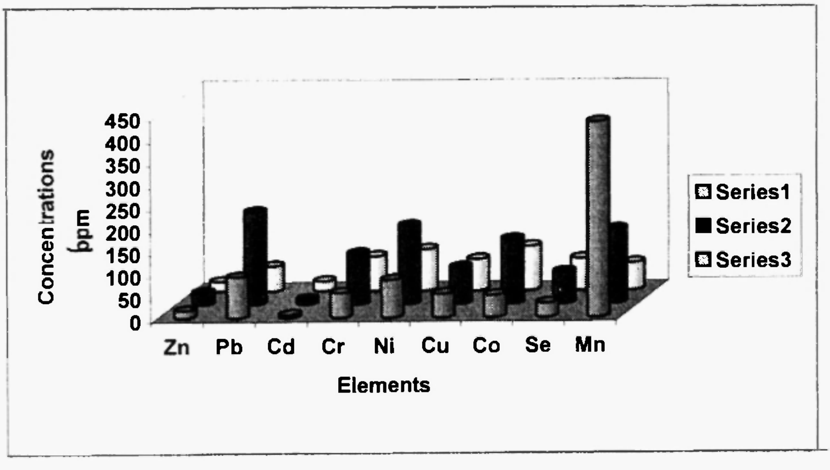
Table 7

The mean concentrations of some heavy metals in soils, in leaves, and in fruits of the Starking delicious collected from VAPH and VGN apple gardens (ppm).

	Metals								
Samples	Zn	Pb	Cd	Cr	Ni	Cu	Co	Se	Mn
Soils	24.2*	92.1	21.7	50.9	97.3	54.7	51.7	32	410.9
SD*** (±)	7.9	17.6	8.4	8.3	27.6	9.9	7.7	6.6	54
Leaves	24.1*	218	29.5	109.7	148.6	104.8	130.1	59.5	185.6
SD (±)	5.9	23.1	6.6	14.5	34.8	28.4	27.2	17.7	24.7
Fruits	21.7**	54.2	16.6	72.5	109.5	76.1	101.8	63.7	61
SD (±)	4.8	9.7	3.4	16.4	20.6	15.5	16.7	17.7	8.5

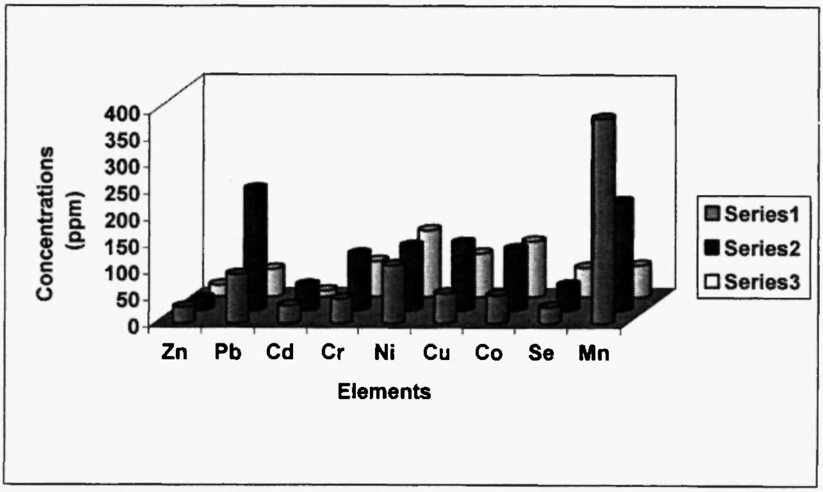
* N=120, ** N=60

*** Standard Devlatlon



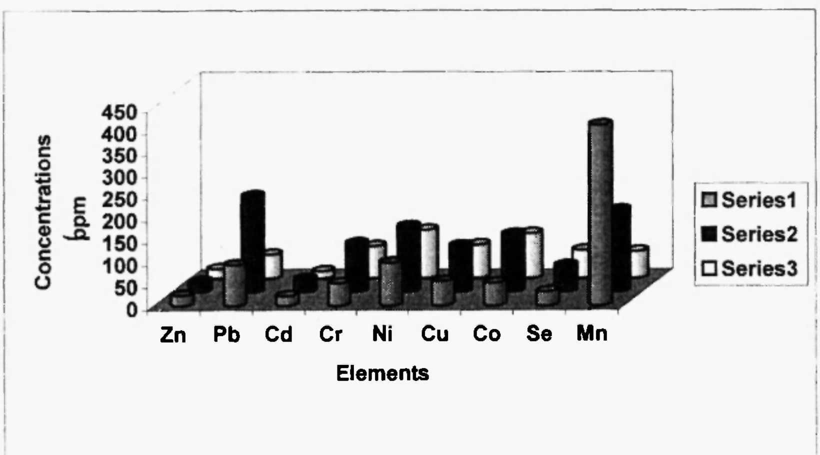
Series 1: In soils; Series 2: In leaves; Series 3: In fruits

Fig. 1: The concentrations of some heavy metals in soil, in leaves and fruits of the Starking delicious collected from VAPH apple garden (ppm).



Series 1: In soils; Series 2: In leaves; Series 3: In fruits

Fig. 2: The concentrations of some heavy metals in soil, in leaves and fruits of the Starking delicious collected from VGN apple garden (ppm).



Series 1: In soils; Series 2: In leaves; Series 3: In fruits

Fig. 3: The concentrations of some heavy metals in soil, in leaves and fruits of the Starking delicious collected from VAPH and VGN apple gardens (ppm).

those obtained from VAPH, but the levels of Cr and Mn are lower. The levels of Pb, Cu, Co and Se are generally the same levels. According to the standard concentrations of heavy metals in soils; the level of Zn is low, the levels of Cr and Mn are normal, the levels of Pb, Cd, Ni, Cu, Co and Se are high. According to the ratio in crust of the earth; the level of Cd is high, the levels of other elements are normal.

In leaves: The levels of Zn, Ni, Co and Se obtained from VAPH are higher than those obtained from VGN, but the levels of Pb, Cu and Mn are lower. The levels of Cd and Cr are generally same levels. According to the standard concentrations of heavy metals in leaves; the level of Zn is low, the levels of other elements are high.

In fruits: The levels of all elements obtained from VAPH and VGN are generally the same values. According to the standard concentrations of heavy metals in fruits; the level of Zn is low, the levels of other elements are high.

The trace elements in soil are extracted to determine their bioavailability, i.e. the quantity of trace elements which can be taken up by leaves and fruits. Four patterns of relationship between the bioavailability of nutrients and uptake in leaves and fruits have been proposed (Table 7). In Type I: uptake decreases from leaves to fruits, such as Zn. Type II: uptake increases from soil to leaves and decreases from leaves to fruits (soil conc.>fruits conc.), such as Pb and Cd. Type III: uptake increases from soil to leaves and decreases from leaves to fruits (soil conc.<fruits conc.), such as Cr, Ni, Cu, Co and Se. Type IV: uptake decreases from soil to leaves and decreases from leaves to fruits, such as Mn.

The mean values between groups (VAPH and VGN; in soils; in leaves; in fruits) were compared by one-way ANOVA. In soil: Zn, Cd and Ni are significant ($p<0.05$); Pb, Cr, Cu Co, Se and Mn are non-significant ($p>0.05$). In leaves: Zn, Pb, Ni, Cu, Co, Se and Mn are significant ($p<0.05$); Cd and Cr are non-significant ($p>0.05$). In fruits: Cd, and Ni are significant ($p<0.05$); Zn, Pb, Cr, Cu, Co, Se and Mn are non-significant ($p>0.05$).

Plants absorb heavy metals from soil as well as from surface deposits on the parts of leaves and fruits exposed to polluted air /25/. Moreover, the presence of heavy metals in fertilizer and volcanic structure of soil contribute the additional sources of metal pollutions for leaves and fruits. Automobile exhaust emissions account for major problems in atmospheric pollution in urban areas /26/. The Van region has volcanic structure of soil and heavy vehicle traffic.

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