Heavy metal transfer to *Beta vulgaris* L., under soil pollution and wastewater reuse

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The use of municipal wastewater for the irrigation of vegetables is a common practice in urban and periurban ecosystems of many countries.

The treated wastewater contains plant nutrients and organic matter, but also contains variable levels of heavy metals.

Plants have a natural ability to extract elements from soil and to translocate them between roots, shoots, and fruits.

The aim …

of the present work is to study and assess the transfer of heavy metals from a heavy metal enriched polluted soil to *Beta vulgaris* under the effect of wastewater reuse.

Experimental Soil

The experimental soil was collected from the top layer (0-30 cm depth) from a non cultivated agricultural area.

Physical and chemical characteristics of the experimental soil

S	**C**	**Si**	**pH**	**EC**	**OM**	**$CaCO_3$**	**VW**
%	%	%		mS/cm	%	%	g/cm^3
56	12	32	6.17	0.206	2.11	0.00	1.48
Cd	**Co**	**Cr**	**Ni**	**Pb**	**N-NO_3**	**P**	-
mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	
0.042	0.424	0.026	2.777	0.856	25	6	-
K	**Mg**	**Ca**	**Fe**	**Zn**	**Mn**	**Cu**	**B** mg/kg
mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	
75	260	>2000	20.09	2.32	33.58	88.55	0.25

S-sand, C=Clay, Si=silt, EC=electrical conductivity, OM-organic matter, VW- volume weight

The soil was a light textured sandy loam (SL)

It was slightly acid, with low electrical conductivity

Medium content in organic matter

The heavy metal composition was very low

Preparation of the pots

The experiment was consisted of 24 pots.
10 kg of dry experimental soil transferred in each plastic pot (10.5 kg of soil with a moisture content 5%).

Six treatment (T1, T2, ….T6) were composed of a mixture of heavy metals (Zn, Mn, Cd, Cu, Co, Cr, Ni and Pb) and the concentration of each metal being 0, 10, 20, 30, 40 and 50 mg per kg soil for the six treatments, respectively.
The six treatments were replicated 4 times.

The bottom of the pots was closed, so that there was no loss of metals due to leaching.
After the preparation of 24 pots was sowing with six seeds of the test plant beet (*Beta vulgaris* L)
The plants were irrigated with treated municipal wastewater (TMWW).

When the cultivation was completed, after 4 months

Chemical Analyses

Soil analysis

included: mechanical analysis, organic matter, pH, available soil P, K, and Na, micronutrients Zn, Mn, and Cu and heavy metals Cd, Co, Cr, Ni, and Pb.

Plant tissue analysis

Plant samples were separated in: above ground plant, beets and roots. The micronutrients Zn, Mn, Cu and heavy metals Cd, Co, Cr, Ni, and Pb were measured by ICP

TMWW analysis

The TMWW was processed and the microelements and heavy metals were determined by ICP

Table . Mean concentration of soil heavy metals determined at the period of the beet harvesting

Treatments	Heavy metals in soil (mg kg^{-1})															
	Zn		Mn		Cu		Cd		Co		Cr		Ni		Pb	
	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
T1	4.058	0.851	82.157	9.105	95.924	11.851	0.932	0.502	0.700	0.246	0.038	0.009	2.696	0.618	2.087	0.570
T2	10.013	1.532	72.412	12.889	14.765	16.245	10.221	1.943	2.983	0.499	0.104	0.058	11.095	2.303	8.267	1.696
T3	17.515	3.496	61.299	11.142	31.034	17.698	20.507	3.386	4.803	0.896	0.205	0.090	18.984	3.735	15.991	2.951
T4	20.719	2.369	55.921	3.448	22.747	12.533	23.433	2.388	7.480	0.555	0.406	0.018	21.844	2.611	18.437	2.645
T5	30.680	6.876	69.692	15.361	39.222	26.461	37.925	6.653	15.527	3.923	1.325	0.381	32.858	6.163	28.994	4.202
T6	39.734	6.575	84.397	17.303	52.162	21.196	47.082	7.444	22.409	2.421	3.079	0.571	39.130	5.109	39.889	6.276

SD=standard deviation

Table . Heavy metal concentration of the above ground plant part, beets and root dry matter of *Beta vulgaris* (µg/g).

Plant Analysis																
above ground																
Treatments	Zn		Mn		Cu		Cd		Co		Cr		Ni		Pb	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
T1	112.8	4.52	895.21	122.86	138.03	29.98	1.81	0.30	0.48	0.08	1.05	0.46	12.20	2.10	0.54	0.35
T2	131.71	14.56	611.91	36.43	87.16	4.41	106.25	11.77	3.73	0.71	2.31	0.54	57.11	7.18	1.91	0.65
T3	125.71	21.27	395.61	27.18	73.37	15.75	100.34	33.74	5.64	1.53	1.91	0.50	70.03	17.12	1.61	0.46
T4	94.55	7.24	412.76	66.90	69.45	12.46	63.18	14.34	7.42	2.59	2.09	0.28	69.55	10.99	1.79	0.56
T5	90.20	8.37	423.26	69.42	76.80	28.09	81.26	22.78	19.48	8.15	4.25	2.95	77.48	9.35	2.29	1.01
T6	102.32	13.95	498.38	78.85	90.67	8.64	109.49	38.92	42.38	20.76	7.40	5.12	96.77	27.91	3.59	1.26
beet																
Treatments	Zn		Mn		Cu		Cd		Co		Cr		Ni		Pb	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
T1	28.83	1.40	131.54	38.13	42.32	10.69	0.11	0.05	0.19	0.01	1.15	1.04	5.36	1.22	0.22	0.14
T2	45.75	3.66	126.62	22.33	45.7	7.53	14.00	1.86	1.37	0.33	0.99	0.14	16.94	3.22	0.45	0.21
T3	47.97	7.24	116.82	37.59	50.24	10.78	21.12	10.60	2.44	0.94	1.41	0.56	19.54	3.05	0.63	0.28
T4	68.33	37.88	145.62	39.55	83.13	23.16	30.85	5.08	4.54	1.95	2.85	2.21	29.19	4.43	1.45	0.94
T5	69.87		152.32		82.01		39.09		10.40		2.65		34.62		1.89	
T6																
root																
Treatments	Zn		Mn		Cu		Cd		Co		Cr		Ni		Pb	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
T1	63.01	8.61	580.22	134.51	354.01	78.83	0.70	0.16	8.04	1.89	22.35	7.01	69.05	6.83	6.30	3.80
T2	63.04	19.09	1025.21	306.27	562.23	252.80	46.80	15.57	21.95	4.99	43.06	10.70	96.07	30.86	18.01	4.37
T3	76.20	6.44	851.13	213.31	661.28	159.25	55.50	12.01	22.08	5.33	36.27	13.30	119.68	12.40	17.35	4.56
T4	89.33	11.16	740.16	216.95	630.37	40.51	75.74	23.61	25.72	5.56	60.39	42.13	140.30	28.44	14.80	3.35
T5	105.45	21.62	649.97	92.58	564.05	172.04	93.24	33.74	34.41	15.32	50.06	17.07	131.92	34.19	11.33	2.41
T6	102.35	22.73	689.69	110.81	401.04	121.25	115.37	20.86	62.80	20.51	45.31	16.89	146.58	35.12	16.89	5.89

Transfer Factor

The transfer of heavy metals from polluted soil to *Beta vulgaris* parts was assessed by means of the Transfer Factor (TF)
Transfer Factor is defined as the ratio of plant dry matter metal concentration (M_{pc}) to the concentration of the same metal in soil (M_{sc})

$$TF = \frac{M_{pc}}{M_{sc}}$$

Then the TF value related to the following parameters …

Transfer Factor relation to soil heavy metal concentration

The relation between Transfer Factor (TF) and DTPA extractable soil metals was found according to regression model to be antagonistic,
i.e. with the increase of soil metal concentration the TF decreases

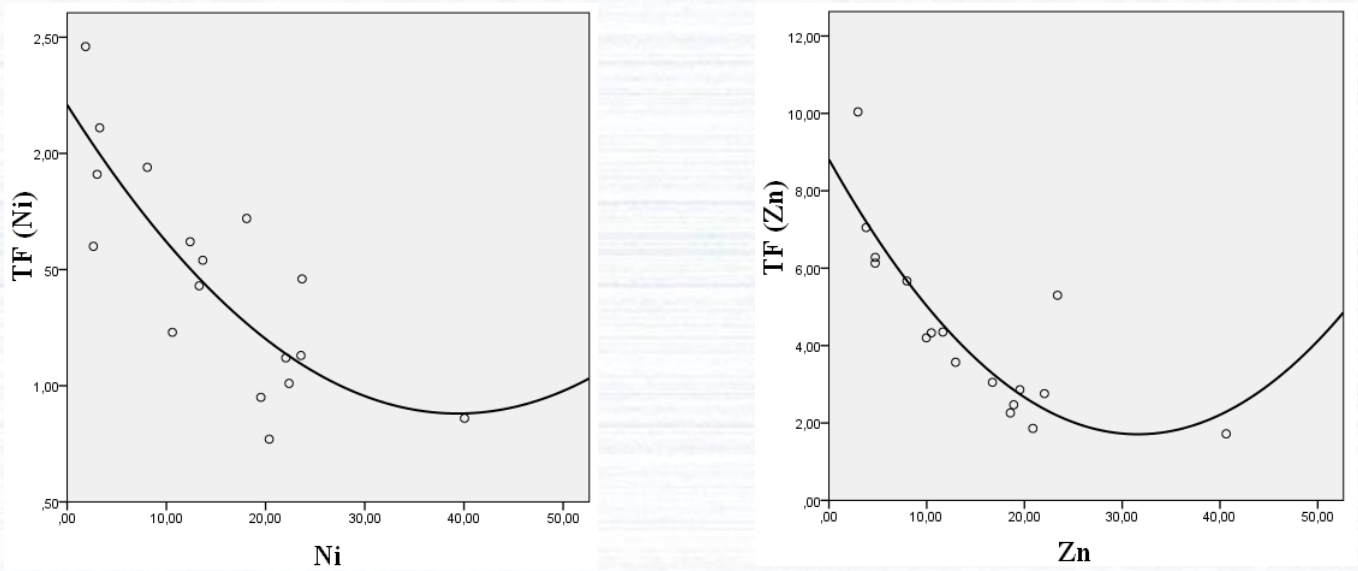


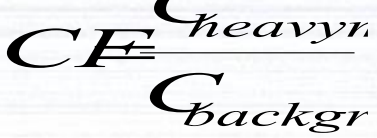
Figure : Relation of DTPA soil extractable Ni and Zn with the respective transfer factor (TF).

Relation between Transfer Factor and pollution indices

The pollution indices used as a tool for the evaluation of soil pollution level.
The soil pollution indices have been studied in the present work:

Pollution Load Index (PLI)

the Concentration Factors (CF) of each heavy metal equal to the ratio of the metal concentration divided by each corresponding reference value, as given by the following formula:

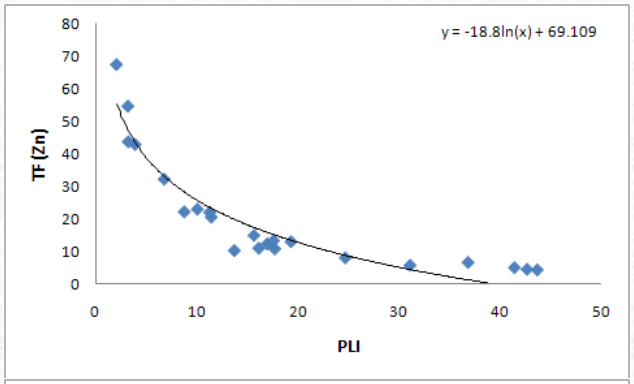


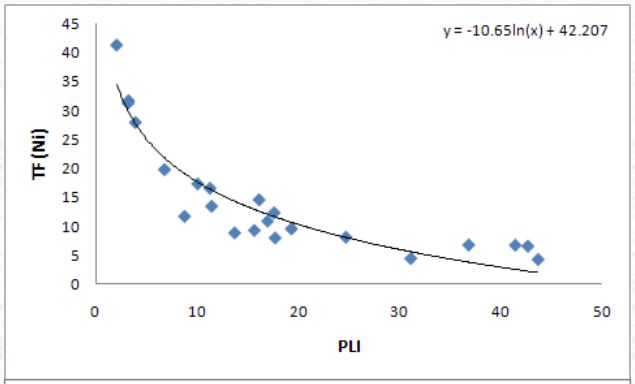
Elemental Pollution Index (EPI)

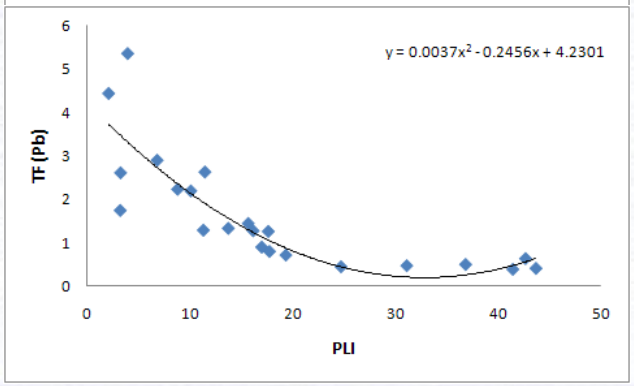
M_1, M_2, M_3,….M_n are the concentrations of soil heavy metals involved in the pollution in mg/kg soil.

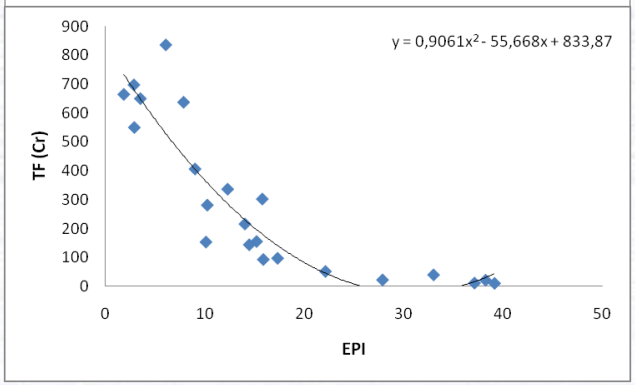
Relation between Transfer Factor and pollution indices

The relationship between the pollution indices and TF of heavy metals from soil to plants showed that it is generally antagonistic (negative).





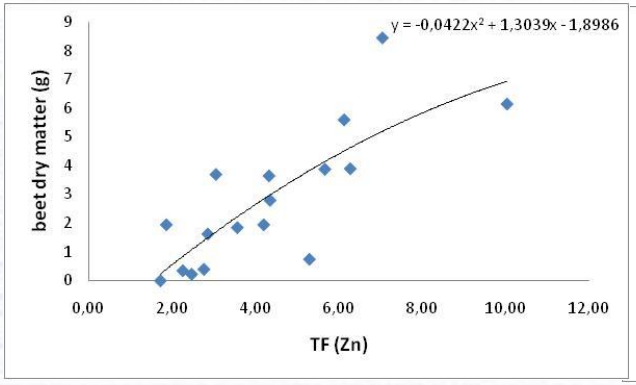


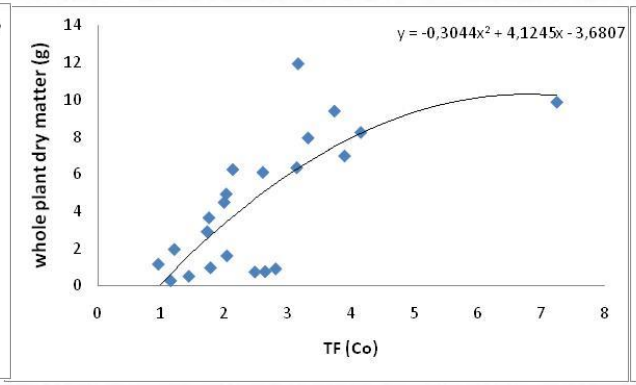


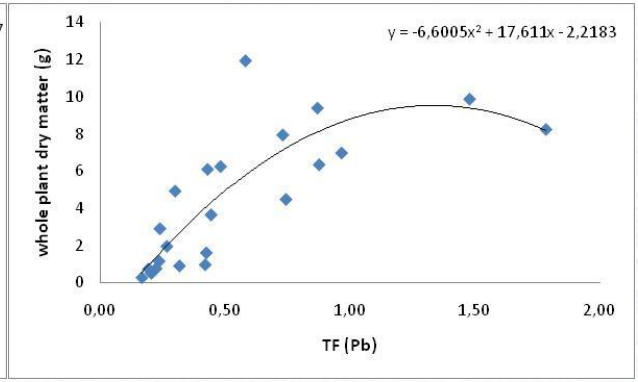
This means that less heavy metal was taken up by the plants due to the toxic effect by the increasing concentration of heavy metals in the soil.

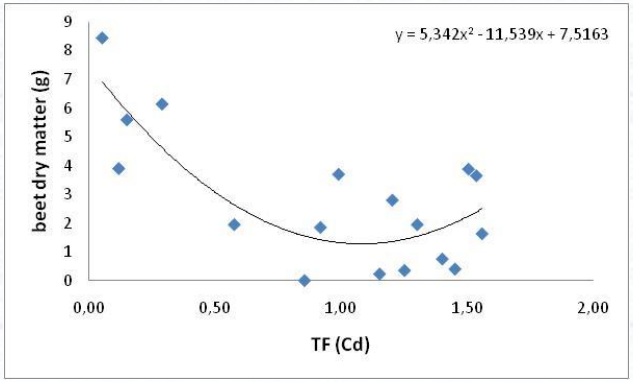
Transfer Factor and plant dry matter

In order to establish a more complete picture of the TF on the plant growth the relation of some characteristic heavy metals TF with the beet and whole plant dry matter yields









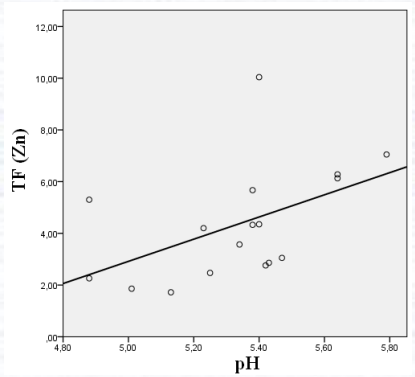
The maximum dry matter yield is attained at a maximum value of TF due to the lower level of pollution.

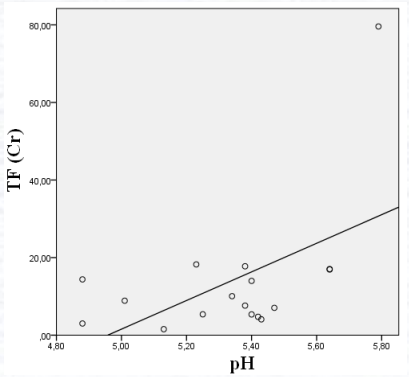
Exception is the case of TF (Cd), the maximum dry matter yield is attained at the minimum value of TF, due to Cd ’s toxic effect on beet.

Transfer Factor and pH

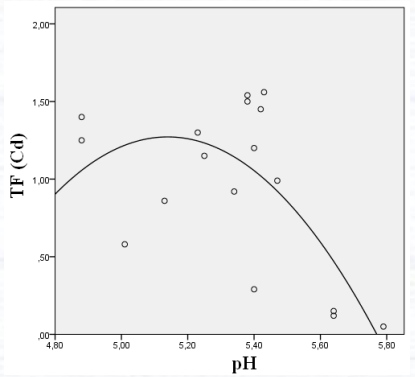
The soil pH, is an important parameter for the heavy metals accumulations in the soil.
Transfer factor is also affected variably by the soil pH, possibly depending on the kind of metal.

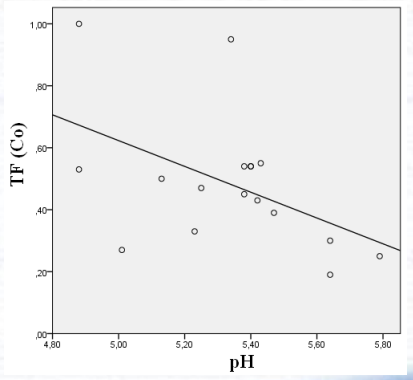
the TF(Zn) and TF(Cr) are affected positively by the increase of pH





the TF(Cd) and TF(Co) are influenced negatively





Conclusions

- The transfer factor (TF) of heavy metals under soil pollution and wastewater reuse was found to be related negatively with the DTPA extractable soil metals, whose concentration increase decreased the TF of the studied metals.

- The applied treatments of the heavy metals mixture decreased statistically significantly the TF. Similarly, the increase of soil pollution level, as assessed by the pollution indices, decreased the TF

- The relation of TF with pH it was found that affected variably the values of the TF i.e. positively and negatively, possibly depending on the degree of solubility and bioavailability of the metals.

THANK YOU FOR YOUR ATTENTION!