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THE IMPACT OF MINERAL ACCUMULATION, ON THE NUTRITIVE VALUE OF RADISH AND LETTUCE

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ABSTRACT

In 2007, a study of the heavy accumulation of minerals in radishes and lettuce, using a randomized complete block of the form of split-plot design, was commenced in three different areas of south of Tehran and was repeated in three phases. The study considered three main factors including plots of land in the SALEHABAD district, DEHKHEIR village and TALEBABAD village, and two sub-factors including irrigation methods such as well water and sewage. Radish roots were found with high amounts of elements such as Nickel (Ni), Lead (Pb), Manganese (Mn), Chromium (Cr), Zinc (Zn) near wastewater irrigation areas in TALEBABAD district, whereas areas near SALEHABAD's sewer system had the lowest uptake levels, thus resulting in different sizes of shoots. Also the size of roots and shoots varied substantially by areas using sewer water, as there were differing accumulations of Ni and Pb, as well as Iron (Fe). It seems that radish leaves were able to control the transfer of Ni and Pb, but tend to guard against the transfer and accumulation of Fe. Thus, to prevent radish leaves absorbing high levels of Pb and Ni from roots, it is recommended not to use irrigation wastewater for radishes. Generally accumulated heavy transfers of minerals in radishes show that the control mechanisms of radishes have been very weak, and have often proven the weakest component of crops studied in the prevention of transmission of the root elements to the leaves, making it near impossible to use radish roots and shoots if wastewater irrigation has been used. All lettuce plants prevent transferring heavy accumulations of minerals in the soil and roots to their leaves, but this control mechanism does not include Ni, and Mn, thus large quantities of these elements were found, have been taken from the root to the leaves. The area near SALEHABAD's sewer system showed the highest concentration of Mn and other heavy elements among 10 regions, including the TALEBABAD. Mineral transfer control mechanisms were so severe that concentration of such minerals to lettuce leaves was much less than that accumulated in radish leaf. The study found among all the plants and vegetables grown for human use, lettuce plant has some of the best preventive measures against mineral accumulation in shoots.

Keywords: radish, lettuce, minerals, accumulation, heavy elements, contamination, sanitation.

INTRODUCTION

Among the dangers to agricultural land and the overall environment is the indiscriminate discharge of industrial sewage to rivers and streams. Environmental researchers have late focused their attention on the presence of minerals in wastewater treatment and their effects on soils and plants cultivated in the region. Often, these elements are a function of the presence of soil, clay, organic matter, and cationic exchange capacity [1, 5, 24, 26]. In the past, this problem has been overcome by applying contamination control standards and use practices to protect water resources and clean contaminated water, much as similar problems of water shortage and contamination were overcome. In countries around the world, studies have looked at the use of urban wastewater irrigation as a nutritional element for plants, as well as using sewage water to supply fertilizer to the plants and save water [8, 18, 21]. Heavy elements in the soil tended to increase with wastewater use in agricultural land and therefore, significantly increase such elements in plants. The nutritional elements that existed in sewage water increased efficiency in plants, as wastewater application increased soil nutrient elements and thus increased soil fertility, with the result that convenient access to high concentration of nutrients, increased growth and biomass of plants under cultivation [9, 23, 29].

Leafy vegetables are grown widely the world over, and are considered important due to their many nutritional benefits. Vegetables such as lettuce, mint, basil, the herb savory, parsley, dill, watercress, spinach and vegetables are rich in vitamins, minerals, proteins and cellulose materials, very important in maintaining our health, and make up a significant part of the daily grocery cart. Typically, where vegetables are produced near big cities and factories, urban and industrial waste water, containing heavy accumulations of minerals, roll into drains. It is noteworthy that these elements generally are not toxic to plants. But they are stored in plants, which could cause health of those humans eating those plants to be compromised [6, 7, 27]. Elements essential for plant growth generally moved in the plant, but heavy transfer of these metals were found in the roots. Most notably, amounts of cadmium, chrome, nickel, lead were maximized in roots [19]. In lands under wastewater irrigation in various countries, with heavy metal concentration in the assembly plant, average cadmium concentration was reported of heavy elements 0.07, chrome 0.16, lead 0.43 and zinc 39.2 milligrams per kilogram in brown rice [13, 15, 32]. Nowadays, local

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research into non-conventional water resources such as wastewater in irrigated lands has become very important [31]. Relying only on instructions provided in other regions of the world were proven wrong and resulted in irreparable long term damage to soil and water resources. Results in a research study on industrial wastewater showed that none of the concentrations of elements Ni, Cd, and Pb were above the limit, but the limitations were noted for wastewater salinity, pH and high concentrations of some positively-charged ions (known as actions), and negatively-charged ions (known as anions) [17, 25, 30]. This study, taking into account the cases discussed above, focuses on the effects of minerals' accumulation on the nutritional value of radish and lettuce plants irrigated with wastewater in three regions of southern Tehran.

METHODOLOGIES

To evaluate and match the effects of irrigation with sewage water and pure experimental design, the experiment was conducted on the area south of Tehran (Rey) in 2006. A randomized complete block split-plot design with three replicates was used for both radish and lettuce plants.

The main factor in three levels of sewage canals in Tehran were monitored for different soil and climates including: **1 -** SHOOR river wastewater in the lands of SALEHABAD region (Agro-Industry JAMARAN), **2 -** FIROOZABAD sewage canal (in agricultural lands of DEHKHEIR village), **3 -** SORKHEH HESAR canal (in agricultural lands of TALEBABAD village). The type of irrigation method was selected as subfactor and was monitored at two levels: 1 - Wastewater, 2 -Well water. One liter sample of wastewater was taken to measure the amount and concentration of heavy metals, Ec, PH and other cases were prepared and submitted to the laboratory. Irrigation water requirements of plants were based on irrigation with wastewater combined (the three canals) and well water, as well as entrance channels for the combined equally with adjustable valves. Soil samples from a sampling depth of 30 centimeters, transferred to the laboratory in air-dried and then crushed-in porcelain mortar, and sifted to a thickness of two millimeters. To prepare extracts of minerals extracted from soil, a mixture was used of two acid including normal HCL 0.05 and sulfuric acid 0.025. For the study of dry-weather soil, five grams of air-dried soil was weighted exactly with the lab scale 0.01 grams and purred in a 100 ml glass jar, and mixed with 20 ml solution extractor for 15 minutes. The material was then filtered using filter paper 42 and was collected in a 50 ml beaker and then brought to the amount of 50 ml by mixing with solution extractor. Then, using the atomic absorption model B1100, the minerals were measured (Table-1). Water samples were filtered by filter paper 42, and the suspended particles separated, as the minerals were measured with atomic absorption equipment (Table-2).

Table-1. Measurements of heavy metals in soil in three different regions (mg/l).

Element	Before test			After test		
	Salihabad (Agro-industry Jamaran)	**Talebabad** (Varamin road)	**Firoozabad** (Aggregation from Firoozabad canal)	**Salehabad** (Agro-industry Jamaran)	**Talebabad** (Varamin road)	**Firoozabad** (Aggregation from Firoozabad canal)
Fe (ppm)	13.1	10	12.7	7.3	10	7.6
Zn (ppm)	16.5	12.4	7	7.5	37.7	25
Pb (ppm)	40	35.3	38.7	25.1	27.7	36.5
Cd (ppm)	1.9	2.8	1.3	2.3	2.3	2
Mn (ppm)	6.2	4.1	3.9	4.7	11.8	5.6
Cr (ppm)	2	20	0.5	10	20	0.5
Ni (ppm)	10	10	10	7	10	10

Samples of the plants were looked over for chemical analysis. Furthermore, samples were observed for one hour at normal temperatures and then in a 70°C oven for 72 hours to remove the plant's moisture completely. Finally, one gram of plant powder was placed in an urn, and positioned into an electric furnace for an entire day at temperatures of 500°C. Afterwards, ash was dissolved in five milliliters of 20-percent hydrochloric acid solution and filtered using filter paper 42.

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Table-2. Measurements of heavy metals in sewage water in regions under test (mg/l).

Element	**Sorkheh Hesar canal** (Upper farm)	**Firoozabad canal** (Upper farm)	**Shoor river canal** (Upper farm)
Fe (ppm)	2.25	1.5	1.9
Zn (ppm)	0.06	0.012	0.007
Pb (ppm)	0.4	0.25	0.6
Cd (ppm)	0.015	0.015	0.018
Mn (ppm)	0.77	0.02	0.008
Cr (ppm)	0.007	0.01	0.009
Ni (ppm)	0.075	0.05	0.1

Extracts of the minerals were collected in a 50 ml beaker, and filled with distilled water to 50 ml to check their atomic absorption. The mix was measured in samples of soil and plant dry powder, respectively 10 and 50 times of read numbers base of milligram element per kg. Densitometer apparatus was used to calculate the elements in water samples, according to mg per liter. The raw data was then compared with an LSD test, after being run through the SAS software for statistical analysis.

RESULTS AND DISCUSSIONS

Radish

A- The impact of sewage water use on mineral accumulation in radish

- The accumulation of minerals in radish shoots in different areas using well water and wastewater for irrigation:

The results in Table-3 show the impact of irrigation with wastewater in different regions, in the accumulation of minerals Fe, Zn, Ni, Pb, Cr and Cadmium (Cd) in radish shoots. The results in Tables 6 and 7 shows that the highest mineral counts were found in SALEHABAD region, and were lowest in the region near TALABABD. It is found that well water and swege treatment only affects the accumulated iron concentration in radish shoots. Tables 5 and 6 show the effects of irrigation with sewage and well water in different areas of mutual sewage on the accumulation of minerals Zn, Ni, Cr, and Cd in radish shoots. The present results can be confirmed in a study by A. A. Azimi *et al*., (2006), which noted an increase of cadmium in radish stems where cadmium nitrate was used.

Table-3. Analysis of variance of heavy metals in radish shoots plant.
Dictionary - View detailed dictionary

Factor	Degree of freedom	Cd	Mn	Cr	Pb	Ni	Zn	Fe
Replication block	2	0.135 ^{ns}	101.580 ^{ns}	0.809 ^{ns}	6.847 ^{ns}	0.953 ^{ns}	196.619 ^{ns}	14887.272 ^{ns}
Main factor (a)	2	6.369**	2405.501 ^{ns}	20.284*	106.287*	1.396 ^{ns}	325.755*	184635.763**
Error (a)	4	0.305	349.471	1.598	10.865	0.828	35.354	4797.508
Sub factor (b)	1	0.307 ^{ns}	1420.375 ^{ns}	0.464 ^{ns}	2.251 ^{ns}	3.018 ^{ns}	35.160^{ns}	63834.745*
Interaction	2	1.882*	720.681 ^{ns}	19.680**	26.012 ^{ns}	21.456**	1647.809**	6844.922 ^{ns}
Error (b)	2	0.248	266.840	1.454	9.525	0.869	89.109	8160.763
Variance coefficients	2	27.80	11.01	28.28	21.71	12.53	9.76	17.22

*, **: Respectively significant in level 5% and 1%
ns: not statistically significant

- Accumulation of minerals in radish roots in different areas, irrigated with well water and wastewater:

Table-4 shows the accumulated amounts of Fe, Zn, Ni, Pb, and Cr found in radish roots in different planting areas affected by sewage. Tables 5 and 6 show the higher amount of these elements found in TALEBABD and the lowest amount found in SALEHABD region Radish roots were also affected by

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well water and sewage treatment, where Ni and Pb values were higher (Table-4). Highest values belonged to the sewage with accumulations of about 1.5 times higher than irrigation with well water (Tables 5 and 7).

Table-4. Analysis of heavy metals in radish plant roots.

Factor	Degree of freedom	Cd	Mn	Cr	Pb	Ni	Zn	Fe
Replication block	2	0.095 ^{ns}	1419.678 ^{ns}	1.363 ^{ns}	0.099 ^{ns}	0.353 ^{ns}	759.490 ^{ns}	987.279 ^{ns}
Main factor (a)	2	0.314 ^{ns}	4009.157 ^{ns}	3.957*	42.242**	5.078*	2715.466*	108176.650 **
Error (a)	4	0.095	1461.819	0.472	0.337	0.469	389.371	9071.077
Sub factor (b)	1	0.617 ^{ns}	1544.568 ^{ns}	1.332 ^{ns}	5.987*	13.456*	2607.438 ^{ns}	21.036 ^{ns}
Interaction	2	1.224*	2966.249 ^{ns}	7.014*	45.004**	11.312 ^{ns}	2390.997 ^{ns}	254330.635 **
Error (b)	6	0.095	802.1447	0.492	0.470	1.936	512.894	9337.477
Variance coeffecience	2	29.12	29.83	21.95	11.32	26.42	24.43	23.00

*, **: Respectively significant in level 5% and 1%
ns: not statistically significant

A comparison chart of legal and natural elements showing accumulation in radish shoots to the average accumulation of plant minerals in radish roots shows that radishes had less Zn and Cd, and thus, less damage to radish roots, but Ni elements (1.5 times), Pb (1.5-2 times), Cr (4-10 times) accumulated several times the legal value in radish shoots and roots and were, therefore, harmful to humans (Tables 5 and 6). Accumulated Mn element in the leaves, was much higher than the normal mineral levels in radish roots, but did not damage the plant. Heavier accumulation of minerals, when used to feed radish leaves, would cause harmful accumulation of minerals in human tissue (Tables 5 and 6). The study by Drmtalh A. Azimi *et al*., (2006) found heavy elements (cadmium) in irrigated radish plants, but not a significant increase in radish roots. Also, in their study, George P. Cobb and colleagues in 2000 found lower accumulation of minerals in radish roots than in leaves.

Table-5. Mean to accumulate heavy metals in radish plants (in terms of PPM).

Plant part	Region	Aggrigation type	Fe	Zn	Cd	Cr	Mn	Pb	Ni
Roots	TALEBABAD	Well water	583.6	103.4	0.5	3.8	51.9	-	-
		Sewage water	462.5	95.0	1.4	24.3	43.3	10.6	7.9
	SALEHABAD	Well water	-	-	-	-	-	-	-
		Sewage water	108.6	37.5	0.1	Trace	17.2	5.05	-
	KHEIRABAD	Well water	250.5	104.8	1.4	1.4	38.0	4.8	2.9
		Sewage water	655.6	104.0	1.5	3.8	131.7	14.1	6.4
Shoots	TALEBABAD	Well water	685.6	96.2	0.5	0.5	144.7	-	8.2
		Sewage water	527.9	96.2	1.9	6.3	166.8	3.4	7.2
	SALEHABAD	Well water	658.6	121.2	3.6	72.1	190.9	9.6	6.3
		Sewage water	499.6	93.0	2.0	20.8	149.4	13.9	9.2
	KHEIRABAD	Well water	408.6	76.9	1.7	4.8	136.1	14.4	9.2
		Sewage water	273.3	107.4	1.4	2.4	128.4	15.6	5.3

Table-6. Standards and amounts of heavy metals allowed in drinking water and irrigation water for agricultural products (in terms of ppm).

Element	Drinking water (International standard)	Drinking water (Europe)	Agricultural products
As	0.01	0.05	0.1
Cd	0.003	0.005	0.01
Cr	0.05	0.05	0.1
Cu	2	0.13	0.2
Fe	0.3	0.2	5
Hg	0.001	0.001	-
Mn	0.5	0.05	0.2
Ni	0.02	0.05	0.2
Pb	0.01	0.05	5
Zn	3	0.15	2

Source: 1. World Health Organization (1993), 2. chapman (1996), 3. poskod (1992)

B- Wastewater effects on vegetative and reproductive characteristics of radish plant

Studies show that in certain regions, wastewater irrigation did not affect radish plant growth. In other words, the selected regions based on the chemical and physical properties of soil, climate, physical and chemical characteristics of specific wastewater did not affect dry weight of shoot and dry weight of root. Probably, it was because the amount of limiting factors (minerals) and fertilizing factors (such as minerals and microelements) in the wastewater was very low in these three regions, where soil and environmental factors were constant, radish plant dry weight did not change. However, given that radish plants have a short growth period (maximum 45 days) and extensive roots, the effects, both positive and negative, of sewage, soil and weather conditions on radish leaves failed to impact radish shoots (Tables 6 and 7).

Table-7. Analysis of variance: growth and reproductive characteristics of radish plants.
Read phonetically dictionary - View detailed dictionary

Factor	Degree of freedom	Root weight	Shoot weight
Replication block	2	14.79 *ns*	15.60 *ns*
Main factor (a)	2	8.59 *ns*	4.36 *ns*
Error (a)	2	46.58	6.67
Sub factor	6	90.62 *ns*	13.34 *ns*
Error (b)	4	20.30 *ns*	4.38 *ns*
Interaction (a * b)	1	38.95	7.70
Variance coefficients		16.0	14.0

*, **: Respectively significant in level 5% and 1%
ns: not statistically significant

There were similar findings regarding irrigation wells. Metals, minerals and microelements from sewage areas showed little effect on any radish plants, although there were differences in areas such elements in well water in the above region (Table-7 and Figure-1). Factors such as well water and sanitation in neither conflict zones, nor dry weight of roots or leaves proved enough to affect the growth of radishes. By contrast, A. Wahid, A. Ghani (2008), in their study, concluded that the use of soil containing Cd and other heavy metals in the planting of vetch bean reduced the absorption of nutrients essential to plant growth, due to interference. So, the amount of dry weight, the number and size of vetch bean leaves - besides other biological factors are being reduced significantly. Moreover, R.P. Singh, M. Agrawal (2008) have concluded that sewage with heavy metals reduced shoot mass, root length and leaf area, unlike S. Aiman Hasan and Partners in 2009. The latter study concluded that heavy metals such as Cd could potentially poison plants and cause growth retardation and interference enzyme activity, due to absorption, transport and deposition in the plant stem.

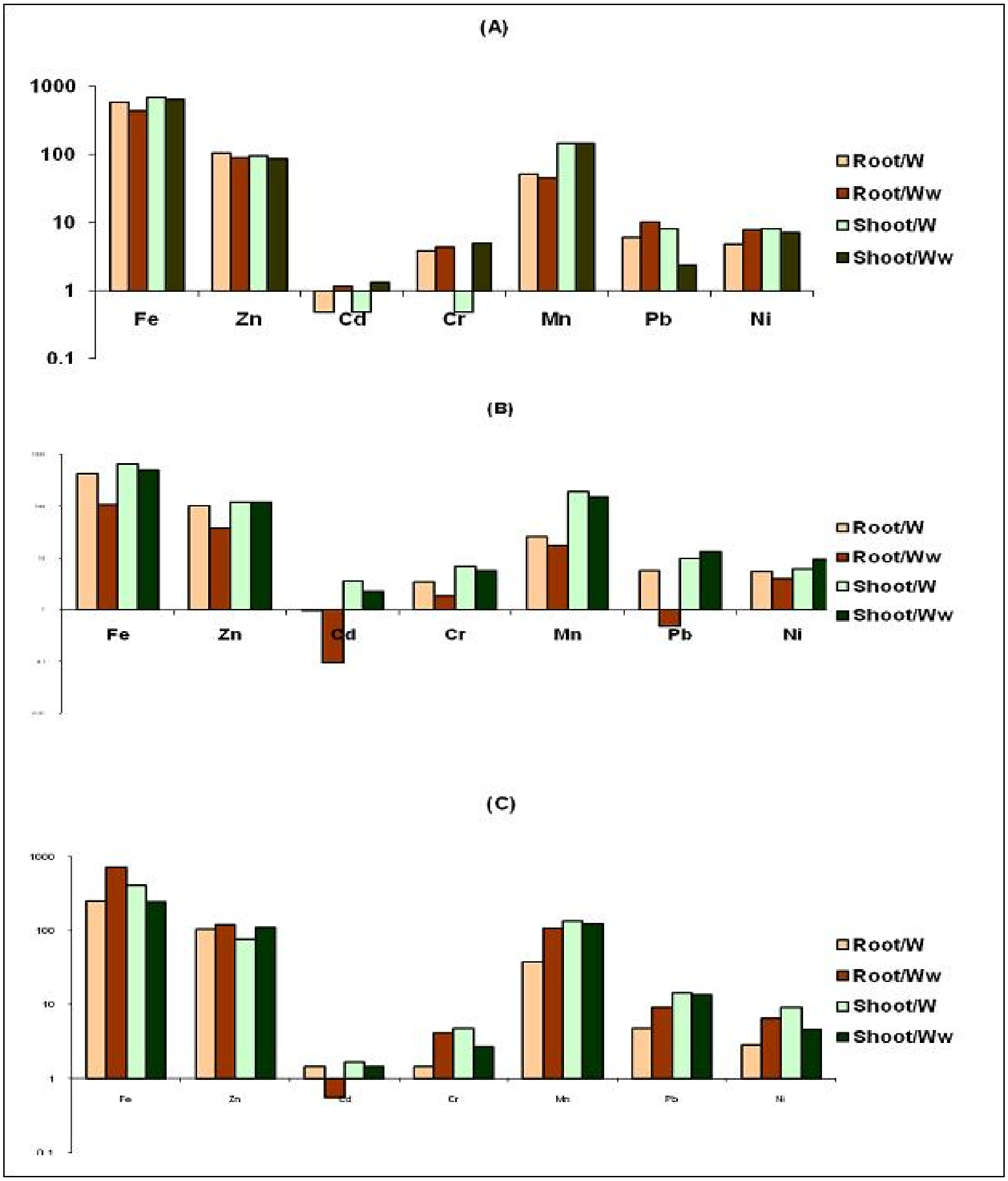

Figure-1. Gathering the elements and heavy metals in radish plants (mg/kg) (PPM).

A. Talebabad W = water

B. Salaehabad (Agro-Industry Jamaran) Ww = wastewater

C. Dehkheir

Table-8. Mean comparisons of heavy metals, growth and reproductive characteristics of radish plants.
Read phonetically Dictionary - View detailed dictionary

		JAMARAN region		DEHKHEIR		TALEBABAD		
Plant part	**Element**	**Control**	**Sewage water**	**Control**	**Sewage water**	**Control**	**Sewage water**	**Mean**
Root	Fe	422.802bc	108.654d	250.481cd	718.213a	583.654	436.538bc	420.06
	Pb	*b* 5.653b	0.481c	4.808b	9.172a	5.991b	10.256a	6.0601
	Cr	*a* 3.481a	1.851b	1.442b	4.136a	3.846a	4.414a	3.195
	Cd	0.994abc	0.096d	1.442a	0.557bcd	0.481cd	1.154a	0.7873
Shoots	Zn	*a* 121.2a	89.05cd	76.92d	110.1as	96.15bc	86.70cd	96.6866
	Ni	*cd* 6.25cd	9.317a	9.135a	4.674d	8.173b	7.136bc	7.443
	Cr	*a* 7.019a	5.580a	4.808ab	2.724bc	0.481c	4.968ab	831.4353
	Cd	*a* 3.606a	2.215b	1.683b	1.442bc	0.4808c	1.330bc	1.7928
Average		108.875	27.1555	43.8398	106.3761	77.4071	96.062	--
Total		871.005	217.244	350.719	851.009	699.2568	552.496	

The means in each row with similar letters did not have significant difference

C- accumulation, transfer coefficients and quantities of heavy metals in the three regions studied

Experts have said radish leaves also work with wastewater irrigation in three regions similar to lettuce, because of transfer values, data aggregation and essential elements, they contain tens of times more of the essential elements than non-essential heavy metals and noxious plants such as Pb, Cd, and Ni. In other words, because accumulated minerals in radish leaves made up most of their required elements, they could minimize harm done to it by the more toxic minerals emanating of the assembly plant and transmission (Table-9).

Table-9. Transfer the amount of elements and heavy metals from soil to radish shoots in the areas cultivated radish plants (values according ppm).

Region	**Ni**	**Pb**	**Mn**	**Cr**	**Cd**	**Zn**	**Fe**
DEHKHEIR	0.5	0.4	32.9	4.8	1.07	15.3	21.5
Standard transfer amount	0.5-1	0.01-0.02 0.02-0.05	-	0.02-0.03	1-3	1-3	-
TALEBABAD	0.7	0.09	40.6	0.3	0.6	7.7	52.7
Standard transfer amount	0.5-1	0.01-0.02	-	0.02-0.03	1-3	1-3	-
SALEHABAD	0.9	0.3	24.09	10.4	1.05	5.6	38.1
Standard transfer amount	0.5-1	0.01-0.02 0.02-0.05	-	0.02-0.03	1-3	1-3	-

Therefore, the highest transfer included Fe, Zn, and Mn. The accumulation of minerals from soil to radish shoots were transferred 10-20 times the standard values. Climatic characteristics, soil structure and texture were studied in three regions had less effect on the transfer of wastewater from minerals from the soil. A comparison of transmission coefficients of minerals from soil to root in the three regions was characterized by the superior strength of radish roots, especially their resistance to minerals passing into parts of the leaves. Therefore, amounts transferred from soil to plant roots were found to be tens of times lower than those within the leaves (Table-10). Waste water and climatic factors and soil in the TALEBABAD region registered a very high concentration of certain minerals from soil to radish roots, which provided transfer coefficients and values so often associated with accumulated minerals in the TALEBABAD area, five to six times the amount of accumulation in the SALEHABAD region. It seems that high accumulation of minerals made consuming radishes leaves virtually impossible and could potentially harm human health. Consuming radish roots irrigated with wastewater in the SALEHABAD area will not harmful to human health, but in other two areas radishes must be irrigated with well water. This table shows the plants in which the highest accumulation of minerals Zn and Mn were found in radish leaves, related to the transfer of tens of times more than standard value, respectively (Tables 9 and 10). Therefore, these products were not recommended for human or animal consumption.

Table-10. Transfer the amount of elements and heavy metals from soil to radish roots in areas under cultivation (values according ppm).

Region	Ni	Pb	Mn	Cr	Cd	Zn	Fe
TALEBABAD	0.7	0.3	10.5	1.2	0.5	6.7	46.2
SALEHABAD	-	0.01	2.7	Trace	0.05	2.2	8.2
DEHKHEIR	0.6	0.3	33.7	7.6	1.1	14.8	51.6

Lettuce

A- Examining the effects of accumulation of minerals in sewage plant lettuce throughout different regions

Mineral amounts accumulated in the dressing area showed significant differences in the presence of Mn and not much difference other metals in lettuce shoots and leaves (Table-11). Comparing farms irrigating their crops with well water and sewage, Ni and Mn findings were significantly different; it was found that only the presence of Ni in lettuce leaves is significantly different for regions with irrigation water wells and sewage (Table-11 and Figure-2). Mineral accumulation in lettuce plants irrigated with well water in three different regions showed that the amounts Mn, Cd and Zn were lower than normal values shown on the normal accumulation Table inside the plants, and therefore, not toxic, thus rendering minimal the risk of lettuce poisoning from certain ions. But it also showed elements such as Ni, Pb, and Cr approximately up to three times the amounts allowed in assembly plants, which could seriously impair in the lettuce's metabolism. The accumulated minerals in lettuce shoots were lower than the allowed amount, therefore humans and livestock were able to consume these vegetables with minimal risk to their health (Tables 6 and 12). In their 2006 study, F. Soumlnmez and M. A. Bozkurt found that the use of wastewater as alternative fertilizer in growing lettuce produced results similar to the results of a discussion surrounding how Zn prevented wastewater from becoming a toxic element, while the amount of available phosphorus in the soil increased. On the other hand, George P. Cobb, *et al*., (2000) concluded that the rate of mineral accumulation in roots and leaf lettuce produced the same amount.

Table-11. Mean to accumulate heavy metals in lettuce plants (in terms of PPM).

Factor	Degree of freedom	Cd	Mn	Cr	Pb	Ni	Zn	Fe
Replication block	2	0.0001^{ns}	11.435^{ns}	0.0001^{ns}	0.099^{ns}	0.686^{ns}	0.0001^{ns}	0.0001^{ns}
Main factor (a)	2	0.807^{ns}	59.946**	0.587^{ns}	33.402^{ns}	0.347^{ns}	936.147^{ns}	1647.941^{ns}
Error (a)	4	0.0001	6.133	0.0001	0.0001	0.686	0.0001	0.0001
Sub factor (b)	1	0.116^{ns}	55.975**	2.887^{ns}	96.188^{ns}	61.154**	53911.778^{ns}	21.036^{ns}
Interaction	2	0.116^{ns}	4.185^{ns}	41.713^{ns}	5.942^{ns}	4.279*	430.383^{ns}	915.1040^{ns}
Error (b)	6	0.0001	7.900	0.0001	0.0001	0.686	0.0001	0.0001
Variance coeffecience		6.52	7.16	7.45	9.12	16.40	17.033	5.12

*, **: Respectively significant in level 5% and 1%
ns: not statistically significant

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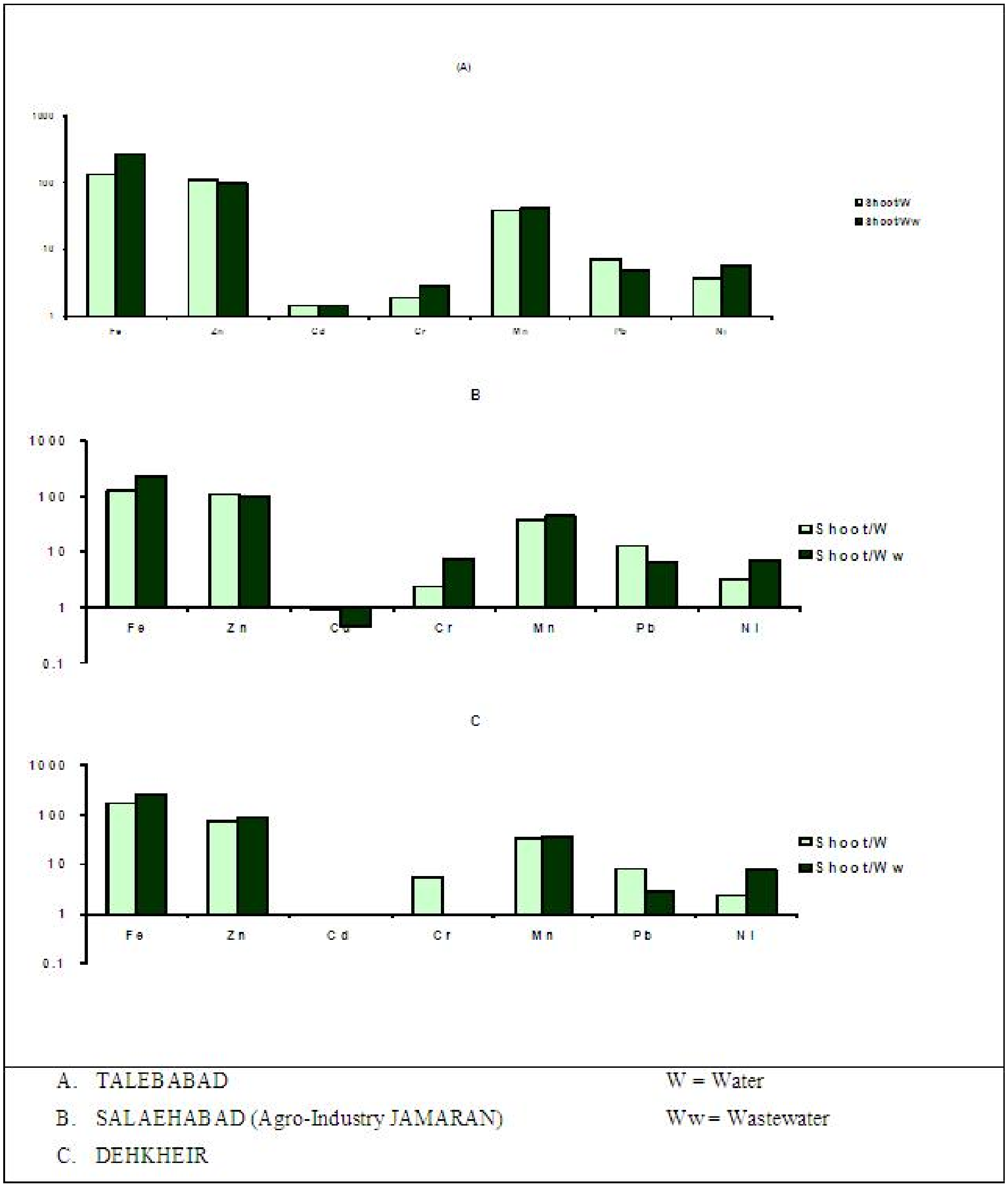

Figure-2. Demonstration of the elements and minerals in lettuce plants (mg/kg) (PPM).

B- Transmission coefficients and quantities of heavy metals in the three regions studied

Although the compactness of values and transfer coefficients obtained for found minerals in wastewater from soil to leaf lettuce, among all the plants being studied was lower, but the transfer coefficients of these metals from soil to leaf lettuce averaged 50 times higher than the standard amount transferred respectively (Tables 6 and 12). Maximum transfer coefficient to leaf lettuce was obtained for Pb, which was 200 times more than the standard amount. Lettuce and other evaluated plants based on the elements required - could control the amount of the elements that transferred, which demonstrated the highest transfer coefficients needed to microelements such as Fe Zn, Mn, and showed the lowest coefficient for poisoning minerals such as, Pb, Cr, Cd, and Ni (Table-12). Mineral amounts accumulated in wastewater irrigation in lettuce leaves in the DEHKHEIR region were shown above 20 percent more than the SALEHABAD area and 50 percent more than TALEBABD area. Thus, in all three regions, wastewater irrigation in growing lettuce may be dangerous, especially in terms of accumulation of Ni and Pb, but lettuce grown with sewer water in TALEBABD district demonstrated least problems in transferring metals from lettuce leaves to the human body (Tables 12 and 13). A study by Pilar Mantildeas *et al.*, (2009) showed similar results to this study, expressing that if farmers used treated wastewater in raising lettuce, it would accumulate the amount of phosphorus, nitrogen, and lead in lettuce roots and shoots significantly more than the standard. Therefore to prevent the toxic effects of these minerals to human health the wastewater irrigation must be done with precise management. While R.K. Rattan *et al*., (2005) believe that using wastewater to irrigate vegetable products causes danger to crops from toxic minerals such as Zinc and Iron, is minimal and can be used in growing these crops.

Table-12. Mean to accumulate heavy metals in lettuce plants (in terms of PPM).

Tested plant part	Region	Aggrigation type	Fe	Zn	Cd	Cr	Mn	Pb	Ni
Shoots	TALEBABAD	Well water	132.2	111	1.4	1.9	37	7.2	3.8
		Sewage water	270.6	97.5	1.4	2.8	40.8	4.8	5.7
	SALEHABAD	Well water	130.2	110.5	0.96	2.4	39.4	12.9	3.3
		Sewage water	233.1	98	0.48	5.7	44.7	6.7	7.2
	KHEIRABAD	Well water	171.1	74.5	0.96	7.6	Trace	8.1	2.4
		Sewage water	258.1	90.8	0.96	0.96	37.5	2.9	11.5

Table-13. Possibility of different plants grown in three different areas of south Tehran sewage.

Region	Elements	Possibility of crop cultivation permissible	impermissible	Solutions
TALEBABAD	Ni,Mn Ni, Pb, Fe	L.s.var.crispum Radish	Lettuce seed -	mixing well water and waste water, well water mixing well water and waste water
SALEHABAD	Ni,Mn Ni,Pb,Fe	L.s.var.crispum Radish	Lettuce seed -	Use of fertilizers and change date of culture well water -seed production
KHEIRABAD	Ni,Mn Ni,Pb,Fe	L.s.var.crispum Radish	Lettuce seed -	Cuture from October well water

CONCLUSIONS

It becomes nearly impossible to consume radish roots and leaves from areas where they are watered with sewage, and where poor control mechanisms are in place. Even so, lettuce plants often accumulated much lower amounts of minerals in their leaves than radishes did. Lettuce plant in areas of greater control, showed lower accumulation of minerals in soil and roots and were able to prevent their transport to the leaves due to the strong control mechanism lettuce possesses. Lettuce plants were thus recognized in this study as plants that could withstand wastewater irrigation. The chill that overtakes the air later in the growing season minimizes the accumulation of minerals, and, hence, the solubility and absorption percentage of them proves far less than lettuce grown in the first half of the year. As a result, the lower absorption of minerals later in the year reduces risk of lettuce’s mineral poisoning to humans.

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