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Accumulation of Heavy Metals in Vegetable Plants Grown in Mostorod Area

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SAMPLES of ten vegetable plant species, namely; *Abelmoschus esculentus* (Okra), *Beta vularis* var. *cicla*, (Chard) *Beta vulgaris* L. (Carden), *Apium geraveolens* (Celery), *Corchorus olitorius* L. (Jews mallow), *Lactuca sativa* (Lettuce), *Allium cepa* (Onion), *Raphans sativus* (Radish), *Eruca sativa mill* (Rocket) and *Spinacia oleracea* (Spinach); were collected from fields at Mostorod area whereas its soils have been subjected to prolonged domestic and industrial wastewater irrigation (about 35 years). Edibal plant samples were air dried, ground and wet digested then analyzed for its heavy metals (Fe, Mn, Zn, Cu, Co, Cd, Ni, and Pb) content using Ion Coupled Plasma (ICP) technique.

Results revealed that vegetable plants species varied in their affinity to accumulate metals in their edible parts. Irrigation with different wastewater significantly increased the concentration of all tested metals in vegetable plants especially the leafy species. Spinach accumulated the highest Fe and Mn levels Rocket accumulated the highest levels of Zn. Pb and Co. However, Jews mallow exhibited the highest levels of Cu, Ni and Cd. These upnormal levels exceed the permissible metals intake as suggested by world health organization (WHO).

It is clear that, the prolonged irrigation with heavy polluted wastewater on the alluvial soils of Mostorod area combined with intensive vegetable cultivation will cause adverse effects on the environment as well as arises health hazard problems. To minimize the environmental hazards: a) wastewater effluents should be treated at sites where toxic metals originate, b) vegetable plants should not be grown under such condition, c) levels of potentially toxic elements needs to be continuously monitored.

Keywords: Pollution, Food chain, Industrial waste water.

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Domestic activities and industrialization have altered the natural biogeochemical cycling of many heavy metals, resulting in the increased mobilization and deposition of toxic amounts of these heavy metals into natural ecosystems. Vegetable crops represent an important pathway for heavy metals from soil to humans (Hansen and Chaney, 1984). Davis and Carlteon (1980) showed that for a wide range of crops trown on sludged soils, the species which accumulated the most Cd were lettuce > spinach > celery > cabbage; for Pb, they were kale > ryegrass > celery; for Cu : sugar beet > some varieties of barely; for Ni: sugar beet > rygerass > turnip; and for Zn : sugar beet > mangold > turnip. Alloway (1995) found that the uptake of Cd by crops decreased in the order: letttuce > cabbage > radish and carrots. Chu and Wong (1987) found greater accumulation of metals in roots than leaves of Chinese cabbage and tomato growing in sludged and composted soils, but carrots contained more in their leaves than the edible root.

Concerning plants growing on contaminated soils of Egypt, several investigators studied the accumulation of heavy metals in these plants. ElSabbagh (1991) found that Cd, Cu, Pb and Zn were accumulated in Vegetable plants growing on contaminated soils in industrial area. Vegetables Cd ranged from 0.03-0.34 mg/l00g as Jews mallow recorded the highest value that was 0.34 mg/100g, followed by Radish with concentration of 0.30 mg/100g. Cu ranged from 0.4-1.2 mg /100g, chicory recorded the highest concentration (1.2 mg/100g) followed by turnip which has a concentration of 1.04 mg/100g. The cultivated vegetables revealed that it absorbs soil Pb with varying concentrations from < 0.4-2.5 mg/100g, green onion ranks the first order as it contains 2.5 mg/100g followed by Radish, which contains 0.7 mg/100g. The average value of Zn content in different vegetables was 9.9 mg/100g. El-Molla (1980) and Abdel-Maksoud (1993) reported that using wastewater for irrigation lead to the accumulation of Fe, Cd and Pb in vegetable crops such as Spinach, Potato. Tomato and Celery growing on polluted soil at Giza Governorate. He found that the egg-plants and the roots of turnip growing in this area gave high amounts of Fe to the level which may be toxic. He noticed that Cd and Pb contents of egg-plants reached to the level which may be toxic to plants and consequently to man. Elsokkary and Sharaf (1993) repored that the bioaccumulation ratio of Zn in the plants followed the order: Chard > Spinach> Coriander > Roquette> Parsley > Lettuce, and that of Cd were: Chard > Spinach > Lettuce > Parsley > Rocket > Coriander.

The aim of this study is to evaluate the potential risk of heavy metals from vegetable plants grown on contaminated soils in the tested area.

Material and Methods

Description of studied area

The studied area (Fig. 1) (Shoubra El-Khima, Bahteem and Mostorod) is about 24.5 km^2 and lies in the industrial area North of Greater Cairo. The studied area encompasses a strange-mixed human activity (e.g; Housing, agricultural and different types of industrial activities). The area suffers from several environmental problems such as sewage and disposal of pollutants from the surroundiug factories, more details are elsewhere (Abdel-Sabour *et al.*, 1998). The agricultural fields were divided to six sectors (A as background delta soil , B as control soil in the area, C, D, E, F, and G as a polluted soils differ in their polluted irrigation water sources (Fig. 1).

Crop samples were collected seasonally during the period Oct: 1993 to May 1995 .Plant samples include Abelmashus, Carden, Celery, Chard, Jews mallow, Lettuce, Onion, Radish, Rocket and Spinach. One gram of oven dried plant material (edible part) was wet digested with concentrated H_2SO_4 /$HClO_4$ acids and then kept for heavy metals determination using Ion Coup Plasma technique (ICP).

Result and Discussion

Uptake of heavy metals by vegetable crops

Samples of ten vegetable plant species were collected and analyzed to determine its heavy metals content as affected by the industrial activities and irrigation with different wastewater in the studied area. Table 1 shows heavy metals content in the investigated vegetable crops. Vegetable plant species varied in their affinity to accumulate metals in their edible parts, especially leafy plants where they contained excessive levels of heavy metals. Irrigation with different wastewater significantly increased the concentration of all heavy metals in the different vegetable plants.

Iron

Plants grown on soils C, G (irrigated with industrial wastewater of Shebin El-Qanater and Mostorod collectors) and D (irrigated with polluted water of El-Shaboura canal) accumulated the highest values of Fe compared to control samples (A and B). An excessive levels of Fe is observed in the studied plants as follows: Spinach > Rocket > Radish > Carden > Chard. The lowest Fe content was observed in Abelmashus (257 µg/g) and Onion (352 µg/g) growing on these soils. Such high levels of Fe in investigated plants not only were ample, but also might reach above the sufficiency range to plant. Jones (1972) reported that the sufficiency range of Fe seems to be from 50 to 250 µg/g. Bowen (1979) reported that the normal level of Fe in edible vegetables ranged between 2-250 µg/g.

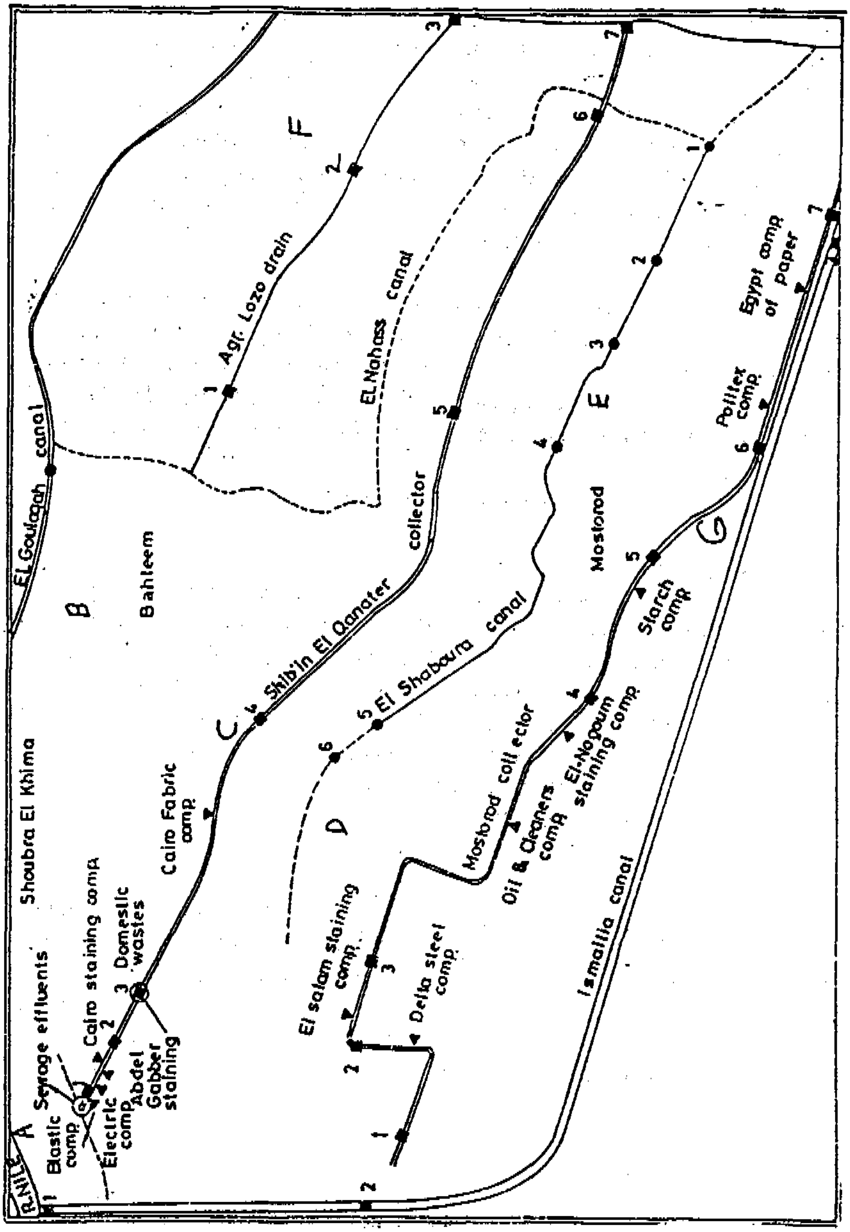

Fig 1: Location of water samples

TABLE 1. Heavy metals concentration (µg/g) in tested vegetables plant grown on contaminated soils in tested area.

Site	Fe	Mn	Zn	Cu	Cd	Co	Pb	Ni
Abelmashus								
A	128	29.5	77.8	5.3	ND	ND	3.5	ND
B	169	45.5	97.0	6.2	0.6	1.6	6.2	0.8
C	286	59.0	224	15.5	3.2	8.5	14.8	3.2
D	228	69.6	148	10.5	2.5	5.8	12.6	2.8
E	186	38.5	122	12.6	1.1	3.2	9.8	0.8
Carden								
A	380	43.5	79	7.6	ND	ND	5	0.6
B	540	66.2	98	8.5	ND	2.7	11	1.0
C	3775	146	242	22.0	ND	15	29	16
D	112	96	158	15.0	ND	11	23	6
E	850	53	138	18.0	ND	6	17	3
Celery								
A	450	29	19	1.5	ND	ND	7.2	0.4
B	191	17	56	5.5	0.8	1.2	9.6	1.8
C	580	27	96	17	4.2	10.1	46	26.5
D	361	19	78	11	3.1	6.2	33	20
E	280	12	63	15	1.8	3.8	24	8.2
G	521	47	123	16	4.6	8.8	41	5.6
Chard								
A	200	76	23	5.2	ND	ND	4.5	ND
B	320	99	39	10.2	ND	1.1	8.5	1.0
C	2196	176	265	27.1	ND	6.6	26	7.6
D	2046	125	208	22.1	ND	4.4	17	5.1
E	1850	69	202	24.8	ND	2.6	13	2.8
G	2117	216	360	26.5	1.2	6.5	23	3.5
A								
B	142	44	21	8.3	ND	ND	6.5	0.5
C	272	68	27	9.8	1.2	1.2	11.2	3.8
D	785	248	78	28.5	0.5	6.5	38.8	21.5
E	560	199	77	17.5	4.7	4.7	25.4	16.2
	460	113	76	22.2	3.1	3.1	20.6	8.5
Lettuce								
A	220	52	41	7.5	ND	ND	3.2	ND
B	380	76	60	8.8	0.9	3.8	14.3	1.3
C	926	108	161	27.6	4.1	22.8	32.5	20
D	828	80	121	14.1	3.6	15.6	26.2	6.8
E	620	40	118	18.5	1.8	9.4	18.2	2.8
G	892	163	223	28.2	3.8	18.6	39.6	2.9
Onion								

TABLE 1. Cont.

A	47	39	12	5.1	ND	ND	2	ND
B	61	59	23	5.7	0.3	0.2	15	1.1
C	325	68	558	8.2	1.8	1.1	34	6.8
D	380	46	43	6.8	1.2	0.8	29	5.2
E	290	29	40	7.8	0.4	0.5	20	1.9
Radish								
A	124	52	10	5	ND	ND	4	ND
B	237	79	44	7	ND	2.1	3.8	1.0
C	3575	181	201	23	ND	11.8	8.5	5.7
D	3313	142	192	18	ND	8.2	7.6	40.8
E	2880	80	182	20	ND	5.1	5.8	1.5
G	3420	215	224	24	1.3	10.8	18.8	1.8
Rocket								
A	325	32	59	8.5	ND	ND	6.5	ND
B	680	47	139	10.8	0.4	3.7	19.9	2.2
C	3898	176	383	26.4	3.6	19.9	72.5	15.2
D	3881	136	303	21.4	2.2	11.2	50.6	9.5
E	2950	71	349	24.5	1.1	6.5	38.5	4.1
G	3920	261	446	ND	3.8	18.7	60.8	8.9
Spinach								
A	869	107	98	11.5	ND	ND	3	0.2
B	1142	127	145	12.5	0.4	2.5	12.5	0.9
C		286	226	25.8	2.1	13.6	39.7	5.8
D	4233	214	203	22.3	1.9	9.8	24.8	3.7
E	3500	179	201	23.8	0.7	3.2	18.6	2.8

Manganese

A high accumulation of Mn in the plants grown on soils of groups C, D and G (irrigated with wastewater). The highest content of Mn was observed in Spinach (214.0-286. µg/g) followed by Jews mallow 198.5-248.0 µg/g), Rocket (136.0-260.8 µg/g with an average of 198.5 µg/g), and Radish (142.0-215.2 µg/g).The lowest values of Mn content was observed in Celery (18.6-27.2 µg/g) < Onion (46.2-68.1 µg/g)< Abelmashus (59.0-69.6 µg/g). These results confirm the serions effect of irrigation with untreated wastewater. Elsokkary *et al* . (1988) found that under normal conditions, the concentrations. of Mn in the leaves of some plant species ranged between 23.5 and 83.7 ppm. Bowen (1979), reported that the concentration of Mn in edible vegetables ranged between 0.3-1000 ppm. Jones (1972) mentioned that the ample concentration of Mn in plant tissues reached to 500 ppm.

Zinc

From Table 1, it is obvious that any tested plant tissue at site G exhibited a remarkable Zn content if compared with control sites (A and B). Sites C,D and E show an enhancing levels of Zn. The highest Zn levels are observed in case of Rocket (average of 374.5 µg/g), Chard (average of 281 µg/g), Spinach (average of 210.0 µg/g), Radish (average of 202.9 µg/g) and Lettuce (average of 170.5 µg/g). Onion plants showed the lowest Zn content (average of 49.2 µg/g) followed by Celery plants (average of 92.5 µg/g) and Jews mallow (average of 76.5 µg/g). This indicates that using wastewater enhances the accumulation of Zn in tested plants. Elsokkary *et al.* (1988) found that under normal conditions, the concentration of Zn in the leaves of some plants ranged between 24.2-309.8 ppm. Bowen (1979) reported that the concentration of Zn in edible vegetables ranged between 1-160 ppm.

Copper

Vegetables grown on sites C and G (irrigated with wastewater of Shebin El-Qanater and Mostorod collectors) exhibited the highest Cu level if compared with other sites. Jews mallow recorded the highest content of Cu (28.5 µg/g) followed by Lettuce (27.9 µg/g), Chard (26.8 µg/g), Rocket (26.4 µg/g), Spinach (25.8 µg/g), and Radish (23.1 µg/g), while the lowest Cu content was observed in Onion (8.2 µg/g). Such high levels are relatively higher than the reported normal limits that mentioned by many authors (Reuther, 1973, and Aboulroos *et al.*, 1996). They reported that the normal level of Cu in plants ranged between 4.0 and 20.0 ppm. Jones (1972) mentioned that toxicity by Cu may be occurred when its level exceeds 20.0 ppm in leaves of plants. Bowen (1979) reported that the concentration of Cu in edible vegetables ranged between 4-20 ppm.

Cadmium

Again, plants growing on sites C, D and G show the highest content of Cd which reflects the cumulative effect of using wastewater in irrigation. Tested vegetables show different affinity to accumulate Cd in their tissues. Jews mallow shows the highest content of Cd (average of 5.6 µg/g) followed by Celery, Lettuce, Rocket and Spinach. Chard, Radish and Onion show the lowest content of Cd (1.2,1.3 and 1.5 µg/g, respectively) while Carden showed zero affinity to accumulate Cd in all sites. These results agree with those obtained by Davis and Caarlton (1980) who reported that the plant species which accumulated the most Cd were Lettuce, Spinach and Celery. Also, Chany *et al.* (1982) and El-Sokkary and Sharaf (1993) found that Lettuce and Spinach showed high affinity to accumulate Cd in their tissues. Such high levels of Cd in investigated plants are above sufficient range. Mengel and Kirkby (1982) reported that the normal levels of Cd in different plant species ranged from 0.1 to 1.0 ppm. Bowen (1979) stated that the normal concentration of Cd in edible vegetables ranged between 0.05 -0.90 ppm.

Cobalt

Presented data show that vegetables grown on soils of groups C, D and G have the highest content of Co in their tissues. Most of the investigated plants accumulated high amounts of Co, which exceeds very much the normal range. Rocket recorded the highest content of Co (61.3 µg/g) followed by Celery, Spinach, Jews mallow, Onion, Lettuce, Chard and Carden. Though Radish and Abelmashus recorded the lowest contents of Co (11.6 and 13.7 µg/g, respectively), these levels exceeds the normal range as reported by El-Sokkary *et al.* (1988). They found that under normal conditions, the concentration of Co in the leaves of some plant species ranged between 0.01 and 4.30 ppm with an average of 2.16 ppm, which is similar to those reported by Bowen (1979). He reported that the concentration of Co in edible vegetables ranged between 0.01 and 4.60 with an average of 2.31 ppm. Also, Aboulroos *et al.* (1996) found that the concentration of Co in the leaves of corn plants growing on non-polluted alluvial soils of Egypt ranged between 0.53 and 1.63 ppm with an average of 1.08 ppm.

Lead

Altough Pb is considered to be relatively insoluble to plant (Koeppe, 1977) tested vegetable plants showed a wide variation of Pb content. Concerning plants grown on soils of groups C, D and G, Rocket accumulated the highest amount of Pb followed by Celery, Lettuce, Spinach; Jews mallow, Onion, Carden, Abelmashus and Radish. Bowen (1979) reported that the normal concentration of Pb in edible vegetables ranged between 0.02 and 20.0 ppm.

Nickel

Presented data showed that Celery accumulated the highest amounts of Ni (23.4 µglg) followed by Jews mallow (19.0 µg/g). Lettuce (13.5 µg/g), Rocket (12.5 µg/g), Carden (11.1 µg/g), Chard (6.4 µg/g), Onion (6.0 µg/g), Radish (5.3 µg/g), Spinach (4.8 µg/g) and Abelmashus (0.80 µg/g). Such levels of Ni in investigated plants are more than the normal level. Bowen (1979) reported that the norml concentration of Ni in edible vegetables ranged between 0.02-4.00 ppm. Aboulroos *et al.* (1996) recorded that the normal level of Ni in the leaves of corn plants ranged between 0.05 and 5.0 ppm.

In general, using the wastewater for irrigation enhances the accumulation of heavy metals in some vegetable tissues above the normal levels. Tested vegetable crops showed variable affinity in the absorption of heavy metals, for example, Spinach accumulated the highest Fe and Mn levels, Rocket accumulated the highest levels of Zn, Pb and Co. However, Jews mallow exhibited the highest levels of Cu, Ni and Cd. These up normal level exceed the levels of metals intake as suggested by O-Connor *et al.* (1990).

Concentration index (Ci)

Kiekens and Camerlynck (1982) proposed a quantitative parameter (Ci) denotes the degree of metal accumulation in the plant and allows the assessment of possible injuries in the sequent food chains.

The values of Ci for the investigated vegetables are given in Table 2. Results show that the magnitudes of increase in the concentration of heavy metals in the investigated plants relative to the control are widely variable among the different plant species. The highest Ci values of the metals with respect to the plants could be regarded as follow: Fe in Radish, Mn in Rocket, Zn in Chard, Cu in Lettuce , Cd in Rocket, Co and Pb in Celery and Ni in Lettuce. It is also clear that the Ci values of the different metals in the same plant species are variable which indicates that the same plant species can accumulate metals from the same soil with different magnitudes.

TABLE 2. Values of heavy metals concentration indices (Ci) in tested vegetables plant grown on contaminated soils in tested area.

Vegetable	Fe	Mn	Zn	Cu	Cd	Co	Pb	Ni
Abelmashus	1.69	1.3	2.3	2.5	5.3	5.3	2.4	4.00
Carden	6.99	2.2	2.5	2.6	0.0	5.6	2.6	13.5
Celery	3.04	1.6	1.7	3.1	5.3	8.4	4.8	14.7
Chard	6.86	1.8	6.7	2.7	0.0	6.0	3.1	7.60
Jews mallow.	2.89	3.7	2.9	2.9	5.4	4.9	3.5	5.66
Lettuce	2.42	1.4	2.7	3.1	4.6	6.0	2.3	15.4
Onion	2.02	1.2	2.6	1.4	6.0	5.5	2.3	6.18
Radish	15.1	2.3	4.6	3.1	0.0	5.6	2.2	5.70
Rocket	5.73	3.8	2.8	2.4	6.0	5.8	3.6	6.91
Spinach	4.78	2.3	1.6	2.1	2.3	5.4	3.2	6.44

Ci = Concentration of an element in enriched plant / concetrarion of Kiekens and Camerlynck (1982).

Risk assessment for human intake

To evaluate the risk on human consume the produced vegetables from the contaminated soils in the tested area, Cd and Pb intake (as an example) will be discussed. As proposed by FAO (1972) the tolerable weekly intake for man in case of Cd is 0.4 0.5 mg / adult person/week. Table 3 shows the amount in kg of tested vegetables to reach these permissible levels. As it could seen from the table, the potential risk increases in case of soils C, D F, and G. The critical high doses are very obvious for vegetables grown on C and G soils. This serious situation is more enhanced if Cd from other sources such as polluted water, meat, fish, dairy products and grains as well as inhalation of polluted air. It is well known that excessive Cd in diet is related to several diseases, such as heart attack, kidney failure and the malfunction of Ca and P metabolism, which causes bone disease.

Concerning, the permissible Pb intake for human, FAO (1972) reported a value of 3 mg/ adult/week. Table 3 shows the amount in kg of tested vegetables to reach this limit. The same potential risk could be observed for soils C, D, F, and G especially in case of rocket, celery and spinach crops. For example, consuming 41 g of rocket/week produced from soil C will reach the highest critical dose, which will have serious impact on consumer health. The situation could be seriously enhanced taking in consideration the mutual impact of other heavy metals intake from different sources.

TABLE 3. Estimated amount of vegetable products (kg) to reach permissible weekly intake for Cd and Pb as proposed by WHO (1972).

	A	B	C	D	E	G
Cadmium						
Okra	Safe	0.833	0.156	0.200	0.455	ND
Celery	Safe	0.625	0.119	0.161	0.278	0.109
Chard	Safe	safe	safe	safe	safe	0.417
Jews m.	Safe	0.417	0.077	0.106	0.161	ND
Lettuce	Safe	0.556	0.122	0.139	0.278	0.132
Onion	ND	1.667	0.278	0.417	1.250	ND
Radish	ND	ND	ND	ND	ND	0.385
Rocket	ND	0.833	0.139	0.227	0.455	0.132
Spinach	ND	1.250	0.238	0.263	0.714	ND
Lead						
Okra	0.857	0.483	0.203	0.238	0.306	ND
Celery	0.417	0.313	0.066	0.092	0.120	0.075
Chard	0.667	0.353	0.116	0.172	0.240	0.133
Jews m.	0.462	0.268	0.077	0.118	0.146	ND
Lettuce	0.938	0.210	0.092	0.115	0.165	0.076
Onion	1.500	0.197	0.088	0.104	0.153	ND
Radish	0.750	0.790	0.353	0.395	0.517	0.160
Rocket	0.462	0.151	0.041	0.059	0.078	0.049
Spinach	1.000	0.240	0.076	0.121	0.161	ND
Carden	0.577	0.278	0.105	0.132	0.182	ND

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تراكم المعادن الثقيلة فى الخضروات النامية بمنطقة مسطرد

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تم جمع عينات من نباتات الخضر المنزرعة بحقول منطقة مسطرد الصناعية حيث يتم استخدام مياه صرف صحي وصناعي في ري هذه الحقول ولمدة حوالي ٣٥ سنة. شملت أصناف الخضر تحت الدراسة الأصناف التالية: البامية - السلق - الفجل - الجرجير - الخس - السبانخ - البصل - الملوخية - البنجر - الكرفس. تم تجفيف العينات هوائيا وطحن وهضم العينات ، تم استخدام تقنية التحليل بأسلوب ICP حيث تم تقدير محتوى بعض العنا صر الثقيلة مثل الحديد ، المنجنيز، النحاس، الزنك، الكوبلت ، الكادميوم ، النيكل والرصاص.

أوضحت النتائج اختلاف أصناف الخضروات في قدرتها على تراكم العناصر تحت الدراسة في الأجزاء المأكولة من النبات. كما أوضحت أن استخدام المياه العادمه (الملوثة) في الري أدت إلى زيادة معنوية في محتوى النبات من العناصر الثقيلة خاصة الخضروات الورقية. أظهرت السبانخ قدرة اكبر على تجميع الحديد والمنجنيز وأظهر الفجل أعلى مستوى للزنك والرصاص والكوبالت بينما كانت قيم النحاس والنيكل والكادميوم اعلى في أوراق الملوخية. وكانت بعض هذه القيم أعلى من المستويات المسموح بها طبقا للمعدلات المقترحة من منظمة الصحة العالمية.

أظهرت النتائج بوضوح أن استخدام المياه العادمة الملوثة بالصرف الصناعي في الري خاصة الأراضي الرسوبية كما هو الحال في منطقة الدراسة مقترنا بالزراعات المكثفة للخضر سوف يشكل خطرا على الصحة العامة وله مخاطر بيئية عديدة . ولتفادي وتقليل هذه الأخطار يجب معالجة المخلفات الصناعية السائلة في نفس موقع إنتاجها (المصنع) قبل السماح بصرفها في المجاري المائية كذلك يجب منع زراعة الخضر ومحاصيل الغذاء الأخرى في مثل هذه المناطق المعرضة للتلوث كما يجب وضع برامج لمعالجة ومتابعة مستويات هذه الملوثات في الأرض - الماء - النبات حتى يمكن تلافي آثارها الضارة.