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Risks of Irrigation with Wastewater on Soil and Plants

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Abstract: Environmental pollution and food safety are two of the most important issues in our time. Soil and water pollution, in particular, have historically impacted on food safety which represents an important threat to human health. It has been observed that agricultural soils have been contaminated due to the use of chemical fertilizers, pesticides, irrigation water and disposal of chemicals nearby. Over the last decades, environmental contamination with heavy metals has increased drastically. Soil pollution with heavy metals will lead to losses in agricultural yield and hazardous health effects as they enter into food chains. Contaminated food through dietary intake has become the main potential risk impacts on human health. This study aimed at investigating the concentration of some cations, anions, macronutrients and some heavy metals in irrigation water and soil, also determine the concentration of the studied heavy metals in six vegetable plants irrigated with treated wastewater from El- Gabal El- Asfar farm (EGAF). The vegetables parsley, tomato, pepper, pumpkin, cucumber and jew's mallow were collected from El- Gabal El- Asfar farm, analyzed for trace metals (Cd, Co, Ni, Pb, Fe, Zn, Cu and Mn) and were compared with the literature reported values. The results indicated that generally, the examined irrigation water, soils and collected plants were heavily contaminated with the heavy metals and exceeded the standard values in most cases.

Key words: Wastewater, heavy metals, vegetables, permissible levels, food safety

1. Introduction

Soils have a very important roles in the environment as they are simultaneously a sink and reactor of various types of pollutants, which makes them also a source of pollutants for other ecosystems components such as groundwater and crops which, in turn, affect public health. Among soil pollutants are heavy metals and metalloids, which are dangerous due to their toxicity, persistence in the environment and their ability to accumulate in soft tissues **(Pinto et al., 2015)**. They enter the body via inhalation, ingestion, and skin

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absorption that whenever they accumulate in body tissue faster than the body's detoxification pathways, a gradual buildup of these toxins will occur.

Most studies of the geochemistry of heavy metals / metalloids have been conducted in urban environments, where the sources of contaminants in soils have strong anthropogenic origin, such as traffic emissions, industrial waste, residential activities. Other works **(Chen et al., 2009)** were carried out at non-urban areas in order to evaluate soil contamination caused by agricultural activities **(Pinto et al., 2015)**. It has been observed that agricultural soils have been contaminated due to the use of chemical fertilizers, pesticides, irrigation water and disposal of chemicals nearby **(Hajar et al., 2014)**.

The term 'heavy metal (loid)' in general with an atomic density greater 6g cm^{-3} includes both biologically essential [e.g., cobalt (Co), copper (Cu), chromium (Cr), manganese (Mn) and zinc (Zn)] and non-essential [e.g., cadmium (Cd), lead (Pb) and mercury (Hg)] elements. The essential elements (for plant, animal or human nutrition) are required in low concentrations and hence are known as trace elements or micro nutrients . The non-essential metal (loid)s are phytotoxic and/or zootoxic are widely known as 'toxic elements'. Both groups are toxic to plants, animals and/or humans at exorbitant concentrations. Health authorities in many parts of the world are becoming increasingly concerned about the effects of heavy metal (loid)s on environmental and human health and their potential implications to international trade **(Park et al., 2011)**.

Trace metals can also be classified as potentially toxic (arsenic, cadmium, lead, mercury, etc.), probably essential (nickel, vanadium and cobalt) and essential (iron, manganese, copper, zinc, selenium, etc.). Toxic metals can be very harmful even at low concentration when ingested over a long time period. The essential metals may also create toxic effects when metal intake is too elevated **(Bash et al., 2014).**

Like many organisms, heavy metals cannot be detoxified by the humans' body mechanism. Instead, they tend to accumulate in different tissues such as liver, muscles and bone and threaten the health of humans. Therefore, the heavy metals are among the most of the pollutants which have received attention in many countries and considered the most dangerous category of pollutants in the nutritional compounds **(Naseri et al., 2015).** Chronic intake of heavy metals above their safe threshold in humans and animals have damaging effects and can cause non- carcinogenic hazards such as neurologic involvement, headache and liver disease **(Sam et al., 2015).**

Vegetables and fruits are some of the most common foods of human diet in all around the human kind. These are rich sources of vitamins, minerals, fibers and also take on as dependable anti-oxidative effects **(Basha et al., 2014)**. Vegetables take up heavy metals and accumulate them in their edible parts in quantities high enough to cause several clinical and physiological problems both to animals and human beings consuming these metal-rich plants **(Amin et al., 2013).**

There are two main sources of heavy metals in the soil: (i) natural background, which represents the heavy metal concentration derived from parent rocks **(Li et al., 2013)**. Apart from Se and As, other elements (e.g., Cr, Ni, Pb) derived via geogenic processes have limited impact on soil **(Park et al., 2011)**. (ii) anthropogenic contamination, including agrochemicals, organic amendments, animal manure, mineral fertilizer, sewage sludge and industrial wastes **(Lu et al., 2015).** Unlike pedogenic inputs, metal (loid)s added through anthropogenic activities typically have high bioavailability. Agricultural and industrial waste materials are the major source of metal enrichment in soils **(Park et a., 2011).**

The bioavailability of metals in soil is a dynamic process that depends on specific combinations of chemical, biological, and environmental parameters. In heavy metal polluted soils, plant growth can be inhibited by metal absorption. However, some plant species are able to accumulate fairly large amounts of heavy metals without showing stress, which represents a potential risk to animals and humans **(Sam et al., 2015)**. The level of plant tolerance to heavy metals is related to the balance between the rate at which metal ions are taken up and the efficiency with which they are detoxified within the plant. Thus the same amount of a metal present in plant tissues may be detrimental for one species while not at all for others **(Hajar et al., 2014)**. Many of plant species have been successful in absorbing contaminants such as lead, cadmium, chromium, arsenic, and various radionuclides from soils. One of phytoremediation categories, phytoextraction, usually can be used to remove heavy metals from soil using its ability to uptake metals which are essential for plant growth (Fe, Mn, Zn, Cu, Mg, Mo, and Ni). Some metals with unknown biological function (Cd, Cr, Pb, Co, Ag, Se, and Hg) can also be accumulated **(Hajar et al., 2014)**.

The main objective of this study was to investigate and monitor the amount of the heavy metal in irrigation water, soil and some vegetables that were collected from EGAF. Furthermore, the levels of the studied heavy metals in the collected samples will be compared with the allowable limits set by FAO/WHO and the national standards. Metal background concentration is important for deciding contamination level, risk assessment of contaminants and understanding effects of past land use practices on the levels of inorganic compounds in soils **(Sanjeevani et al., 2015)**.

2. Materials and Methods

Site description

Survey studies were carried out in El- Gabal El- Asfar farm (EGAF) during the spring season of March 2016, irrigated with treated sewage effluent from El- Gabal El- Asfar Wastewater Treatment Plant. EGAF, which is receiving treated sewage effluent (TSE), as the only source of irrigation from El- Gabal El Asfar Treatment Plant, for more than 100 year**.** It is one of the famous farms in Egypt. The farm had been devoted for the disposal of the treated sewage effluent of Cairo city. The farm is located in the eastern desert, 25 Km north east Cairo. The soil is fertile and rich in organic matter and is classified as loamy- sandy soil (**Abd- El Lateef et al. 2006**). Citruses are the main trees grown in the farm. There are some field crops such as maize, peanut, eggplant, okra, clover, cabbage, wheat, turnip, lettuce, broad bean, onion, garlic, cauliflower, tomato, parsley, strawberry and potato commonly cultivated in the farm. Beside these crops, date palm and pecan nuts are also growing in the farm **(El- Motaium and Badawy, 2000).**

Irrigation water (treated sewage effluent), soil and some vegetables cultivated crop samples were collected. Water samples were collected in triplicate from sources of irrigation canal and were kept in plastic bottles in a cool place. Analyses of water samples were determined according to the standard methods of **Chapman and Pratt (1961)**. The macronutrients (NPK) were determined according to **Chapman and Pratt (1961)**. The heavy metals (Pb, Cd, Co and Ni) and micronutrients (Fe, Zn, Cu and Mn) were determined using Atomic Absorption Spectrophotometer (Perkin Elmer 3300).The soil samples were collected in triplicate, each collected soil sample was undertaken to represent the soil profile supporting one of the growing plant species involved in the present study. The soil samples were taken at two depths 0-30 cm and 30-60 cm using a soil Dutch auger and were put in polyethelene bags. Surface litter was first scraped away at each sampling spot to remove plant debris. Samples were collected from three sites in addition to, virgin soil (uncultivated soil) as a control. The samples were air dried, crushed gently, sieved through a 2mm sieve, mixed thoroughly and stored in polyethylene bags for analysis. Physical and chemical properties of the investigated soil were determined according to the standard methods of **Page et al., (1982)** and **Clark et al., (1986)**. The pH was measured using a pH meter in soil suspension (1:2.5) soil-water ratio, Electrical conductivity (EC) was determined in the saturated soil paste, available macronutrients were determined as outlined by **Black (1965).** Available micronutrients were extracted using ammonium bicarbonate-(DTPA) and were determined using Inductively Couped Plasma (ICP) Spectrometry model 400, as described by **Soltanpour and Schwab (1977)**.

The plants were collected separately. The details of the different selected plants during the study are given in Table 1. The collected plant samples were brought back to the laboratory and washed with clean tap water to remove the soil particles adhered to the surface samples and to remove airborne pollutants. After removing the extra water from the surface samples with blotting paper, the samples were air – dried, placed into separate bags and were oven- dried at $70C^0$ until constant weight was achieved. The plant samples content of some micro- nutrients (Fe, Mn, Zn and Cu) and some heavy metals (Pb, Co, Ni and Cd) were determined using atomic absorption spectrophotometer (Parkin Elmer 3300) according to **Cottenie et al., (1982)** and were determined using Inductively Couped Plasma (ICP) Spectrometry model 400, as described by

Soltanpour and Schwab (1977). The data of water and soil samples were subjected to statistical analysis according to **Sndecor and Cochran (1989)**, where means value were compared using L.S.D. at 5 % level. The irrigation water, soil and plants content of heavy metals and micronutrients were compared with the permissible limits.

Table1. List of the studied species, their families and the studied parts

The common name	The scientific name	The family	The studied part
Parsley	*Petrosolinum sativum*	Umbelliferae	Shoot system
Tomato	*Solanum lycopersicum*	Solanaceae	Fruits
Pepper	*Capsicum annum*	Solanaceae	Fruits
Pumpkin	*Cucurbita pepo*	Cucurbitaceae	Fruits
Cucumber	*Cucumis sativus*	Cucurbitaceae	Fruits
Jew's mallow	*Corchorus olitorius*	Tiliaceae	Shoot system

3. Results and Discussion

Irrigation water

Chemical analysis of irrigation water

The results present in Table 2 (Fig. 1) show the values of some chemical characteristics of irrigation water used in EGAF during the present investigation. The data showed that the EC value increased non significantly in TSE as compared with the corresponding control (the River Nile). The pH value of TSE was slightly alkaline in TSE as compared with the control. **Rattan et al.,(2005)** recorded that the tolerance limit of pH for irrigation water ranged from 6.0-9.0. Thus, pH of the TSE is within the permissible limit. Data given in Table 2 showed that the values of Mg^{++} and macronutrients (N, P and K) increased significantly in TSE as compared with the corresponding control. Meanwhile, there was not any significant increase or decrease in values of EC, Ca^{++}, Na^{+}, K^{+} , the studied anions and SAR of TSE as compared with the control. Comparing the values of EC, pH, soluble cations and soluble anions and SAR of TSE with the standards limit for irrigation according to **FAO (1985)** and **FAO: Pescod (1992)** also, with the References limit for recycled wastewater **USEPA (2004)**, it was found that all the studied parameters were within the standard limits, except the Mg^{++} and K^{+} which exceeded the permissible limit according to standards limit for irrigation according to **FAO (1985) and FAO: Pescod (1992).** Also, pH value exceeded (slightly increase) the permissible limit according to the References limit for recycled wastewater according to **USEPA (2004)**.

The results have indicated that application of TSE in irrigation led to a significant difference in the concentrations of both Mg^{++} and the macronutrients (N, P and K) between TSE (treated sewage effluent) and the control (The River Nile), while EC value, the concentrations of Ca^{++}, Na^{+}, K^{+}, the anions and SAR value did not show any significant difference between TSE and the control. The data presented in Table 2 show the values of the tested heavy metals (Cd, Co, Ni and Pb) and micronutrients (Fe, Zn, Cu and Mn) in irrigation water samples. The concentration of these studied elements were higher in TSE (except in Pb) as compared with the control (the River Nile). For example, the values of Cd, Co, Ni, Fe, Zn, Cu and Mn increased by 150.0% , 200% , 933.33%, 156.66%, 51.28%, 225.0% and 10.56%, respectively in TSE as compared with the corresponding values of the control. Comparing the values of the tested heavy metals and micronutrients of TSE used in irrigation at EGAF (Table 2) with the permissible limits regulated by **FAO (1992)** and **The Egyptian Code (2005**), it could be observed that the levels of heavy metals (except Co and Ni) and the micronutrients (except Mn) are within the permissible limits. These results is agree with those of **Singh et al., (2010b).**

It shoud be mention that heavy metals are generally not removed even after the treatment of wastewater at sewage treatment plants, and thus cause risk of heavy metal contamination of the soil and subsequently to the food chains **(Fytianos et al., 2001** and **Singh et al., 2010b).**

Soil analysis

All soil chemical characteristics were carried out in the surface layer (0-30 cm) and the subsurface layer (30-60 cm). The data presented in Table 3 (Fig. 2) showed that in both of two layers the values of EC, soluble cations and anions (except HCO_3^-) decreased significantly in soil under irrigation with TSE as compared with the virgin soil. The pH value slightly decreased in soil irrigated with TSE as compared with the virgin soil. This finding is in agreement with those of **Sikka et al., (2009)** who indicated that the mean values of pH in soil irrigated with sewage water were lower as compared with tube- well irrigated soils. They also, cited that the continuous application of sewage water led to lower pH which may be due to acidic nature of effluents and to loading of organic substances. The authors added that the variations in the values of pH may be due to the chemical characteristics and the amount of effluents used for irrigation. The sewage water used in irrigation contains large amount of organic matter and the release of organic acids during the decomposition of organic matter may also be responsible for decrease in pH of sewage irrigated soils. According to **Indian standards (1983)** and **Awashthi (2000),** the concentration of all the studied cations within the permissible limits. Meanwhile, the value of sulphate exceeded the permissible limit.

Table 2. Some chemical characteristics, macronutrients content, heavy metals and micronutrients content of treated sewage effluent used for irrigation in El- Gabal El - Asfar Farm (EGAF)

The studied parameters	The control (the Nile River)	TSE	LSD at 0.05	Standard limit FAO (1985,1992)	The References limit USEPA(2004)
EC	0.87	1.02 **dS/m** (1020 **μs/cm)**	**0.46 (n.s.)**	3000	**0.2**
pH	7.21	8.27	**0.47**	6.5-8.5	**8.1**
SAR	1.68	8.54	**0.71 (n.s.)**	**-**	**6**
Cation meq/l					
Ca^{++}	3.19	1.57 (31.46 ppm)	**2.13(n.s.)**	**400 ppm**	**120 ppm**
Mg^{++}	2.42	5.59 (67.97 ppm)	**1.8**	**60 ppm**	**50 ppm**
Na^{+}	2.85	2.57 (59.11 ppm)	**1.78 (n.s.)**	**900 ppm**	**200 ppm**
K^{+}	0.28	0.26 (10.16 ppm)	**0.10 (n.s.)**	**0.2 ppm**	**40 ppm**
Anion meq/l					
CO_3^{--}	0	0		**6 ppm**	**-**
HCO_3^{-}	3.38	2.63 (42.34 ppm)	**1.73 (n.s.)**	**600 ppm**	**-**
Cl^{-}	1.98	1.8 (63.82 ppm)	**1.24 (n.s.)**	**1100 ppm**	**360 ppm**
SO_4^{--}	3.38	5.58 (268.8 ppm)	**3.14 (n.s.)**	**1000 ppm**	**-**
Macronutrients (ppm)					
N	2.69	5.34	**1.31**	**-**	**-**
P	0.7	1.13	**0.06**	**-**	**-**
K	7.06	8.54	**0.67**	**-**	**-**
Heavy metals (ppm)			**FAO (1992) ppm**	**The Egyptian Code (2005) ppm**	
Cd	0.004	0.01	**0.010**	**0.010**	
Co	0.03	0.09	**0.050**	**0.050**	
Ni	0.03	0.31	**0.200**	**0.200**	
Pb	0.31	0.04	**5.000**	**5.000**	
Micronutrients (ppm)					
Fe	0.90	2.31	**5.000**	**5.000**	
Zn	0.39	0.59	**5.000**	**5.000**	
Cu	0.04	0.13	**0.200**	**0.200**	
Mn	0.003	0.32	**0.200**	**0.200**	

Where n.s. means non significant and TSE means treated sewage effluent

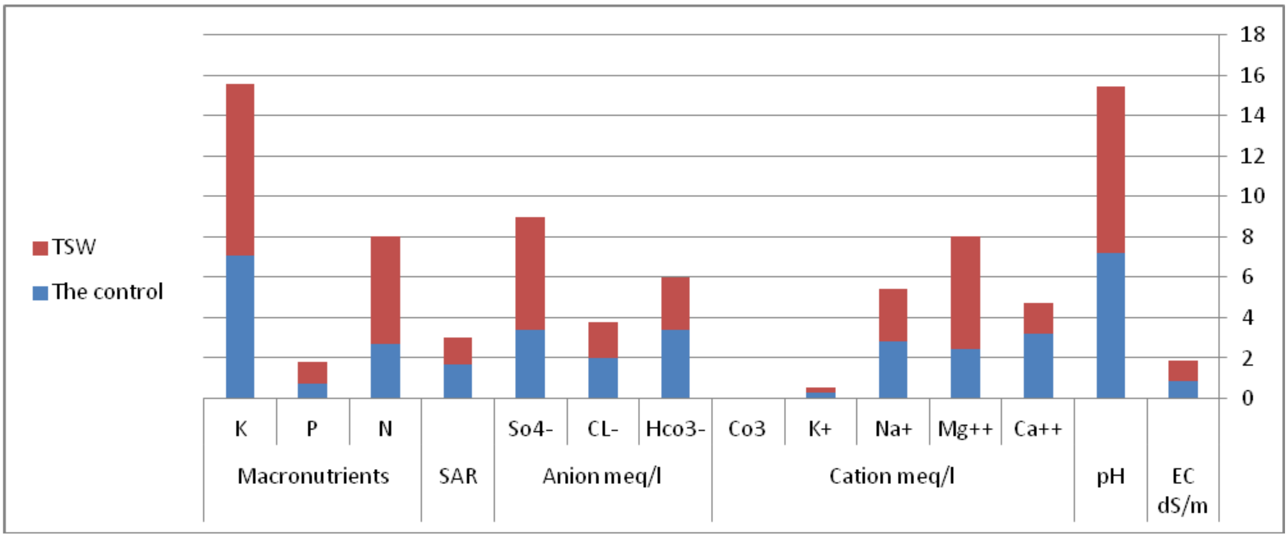

Fig1. - The chemical characteristics of irrigation water.

Regarding to soil texture, the data in Table 4 indicated that before sewage application, the soil was sandy in texture at the soil layer 0-30cm of virgin soil and upon prolonged treated sewage application, there was change in soil texture. The textural class of soil irrigated with TSE was sandy loam (in most cases). With respect to organic matter, the data indicated that the OM content in the soil irrigated with TSE increased significantly in both layers 0-30 cm and 30-60 cm as compared with the virgin soil, this result is in agreement with **Khafagi et al., (2012). Jan et al., (2010)** cited that Long term application of wastewater resulted in an increase in organic carbon and reduction in soil pH which might result in the remobilization of metal pool to more mobile fraction. The data presented in Table 4 indicated that the value of N decreased significantly in both two layer of soil irrigated with TSE as compared with the virgin soil. On the other hand, the mean value of P of soil irrigated with TSE increased non significantly in the soil surface and significantly in the subsurface layer as compared with the corresponding control. **Yadav et al., (2002)** reported that the changes in nutrients content of soils reflected in uptake by winter crops (wheat, berseem) and summer (rice, sorghum) crops growing in the contaminated sites. According to **Indian Standards (1983) and Awashthi (2000)** the soil content of P within the permissible limits.

Data given in Table 5 declared that in soil irrigated with TSE, the soil content of heavy metals and micronutrients increased (except in a few cases) in both the surface and the subsurface layers as compared with the corresponding controls. This finding is in agreement with those of **Jan et al., (2010)** who indicated that the bioavailability and total metal concentrations increased in soil irrigated with wastewater as compared to back-ground and control soils (virgin soil). There are many factors that can influence the concentration of heavy metals in soil and their upon ecosystems, such as soil parent material types, climate, and anthropogenic activities (**Qiao et al., 2010)**. Although the amounts of DTPA-extractable metals do not absolutely represent the actual quantities of soil metals that can be taken up by plants, they do appear to be good indicators of the potentially bioavailable quantity **(Zhuang et al., 2009**). Generally, the concentration of these heavy metals and micronutrients was much higher in the surface layers (except in a few cases) than in the subsurface layer. The concentration of the tested heavy metals and micronutrients followed the order (in most cases) Fe >Zn >Pb>Mn>Cu>Ni>Co> Cd. In general, it seems that heavy metals tend to accumulate in the surface soil layers, and that strong binding force with clay minerals and organic matter limit their movement. Our results are in good agreement with those reported by **Kiziloglu et al., (2008). Nyamangara and Mzezewa (1999**) added that the accumulation of Zn, Cu, Ni and Pb to the surface soil depth can be attributed to the high affinity of the metals to organic matter. Since organic matter and pH are the most important factors that control the availability of heavy metals in the soil.

In the present study, comparing the soil content of heavy metals and micronutrients with the permissible limits according to **Indian standard (1983); Awashthi (2000), Candian (2011)** and **Dutch(VROM 2000) guidelines (Pinto et al.,2015)**, it was found that the mean values of soluble heavy metals and micronutrients of soil irrigated with TSE were within the permissible limits. **Singh et al., (2010b)** recorded that the lower concentrations of heavy metals than the safe limits at wastewater irrigation site may be due to the continuous removal of heavy metals by vegetables and cereals grown in this area and also, due to leaching of heavy metals into the deeper layer of the soil. Metals due to their non-degradable nature are extremely persistent in the environment, and thus readily accumulated at toxic levels. Metals can also accumulate in the soil at toxic levels due to long term application of wastewater (**Sharma et al., 2007**). **Hajar et al., 2014** reported that the bioavailability of metals in soil is a dynamic process that depends on specific combinations of chemical, biological, and environmental parameters.

Table 3. Some chemical characteristic of soil irrigated with TSE in EGAF

Plant	Depth cm	Particle size distribution				Texture class	$CaCO_3$ %	O.M.%	Macronutrients (ppm)		
		Coarse sand	Fine Sand	Silt	Clay				N	P	K
Parsley	0-30	12	44	26	18	Sandy loam	1.25	2.27	63.1	3.24	145.20
	30-60	31	46	12	11	Sandy	1.9	0.92	54.12	2.97	112.40
Tomato	0-30	18	67	9	6	Sandy	1.46	3.3	76.2	3.35	166.11
	30-60	27	41	20	12	Sandy loam	1.66	2.06	85.11	2.96	43.12
Pepper	0-30	21	37	25	17	Sandy loam	1.9	4.74	74.11	2.07	94.33
	30-60	30	49	11	10	Sandy	2.13	3.22	61.33	1.82	85.17
Pumpkin	0-30	17	41	32	10	Sandy loam	2.02	2.75	64.12	3.22	165.11
	30-60	16	58	12	14	Loamy sand	0.44	1.87	55.4	2.14	106.24
Jew's mallow	0-30	20	37	28	15	Sandy loam	2.34	4.12	94.33	1.23	189.03
	30-60	18	61	10	11	Loamy sand	0.76	3.35	55.4	0.83	102.19
Cucumber	0-30	19	39	26	16	Sandy loam	2.54	3.34	74.53	0.87	85.54
	30-60	15	29	24	32	Sandy clay loam	2.16	2.16	62.18	1.4	97.35
Virgin soil (control)	0-30	28	56	11	6	Sandy	2.33	0.99	93.00	1.14	132.30
Mean of soil profiles		17.83	44.17	24.33	13.67		1.91	3.42	74.398	2.33	140.88
LSD at 0.05							**1.91(n.s.)**	**1.05**	**13.06**	**1.28 (n.s.)**	**48.62 (n.s.)**
Virgin soil (control)	30-60	20	48	19	13	Sandy loam	2.05	0.84	84	0.83	107.03
Mean of soil profiles		22.83	47.33	14.83	15.00		1.5	2.26	62.25	2.01	91.07
LSD at 0.05							**0.85(n.s.)**	**1.05**	**13.56**	**0.99**	**29.26 (n.s.)**
Indian standards (1983) and Awashthi (2000) mg/Kg-1							-	-	-	0-20	-

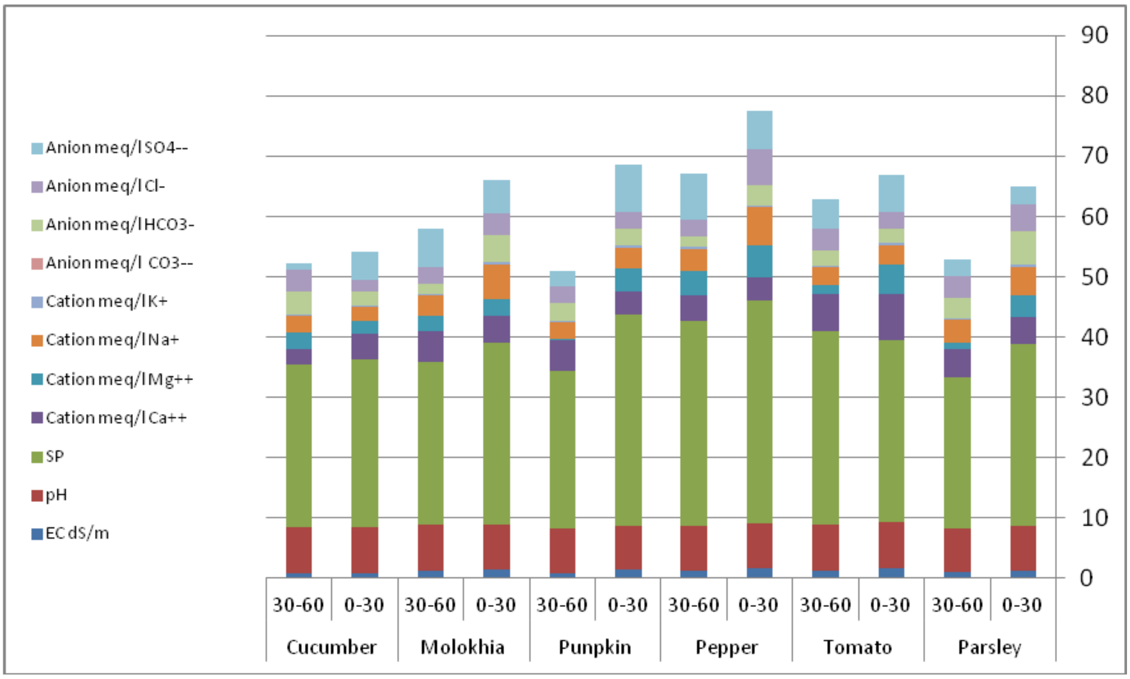

Fig. 2- Some chemical characteristics of soil irrigated with TSE from EGAF.

The results present in Table 6 (Fig. 3) show that the plants content of heavy metals and micronutrients differed from plant to another. Also, from part to another part in the same studied plant. The plants differ in accumulation and distribution of metals in their different parts (root, shoot, leaves, and fruits/ seeds) and the efficiency of different crop plants in absorption and distribution of metals are judged either by plant metal uptake or by transfer factor of metals from soils to plants **(Chandara et al., 2009)**. The translocation process of metals from root to shoot includes long distance in xylem and storage in vacuoles of leaf cells and it is affected by several factors. Absorption capacity of heavy metals depends upon the nature of vegetables and some of them have a greater potential to accumulate higher concentrations of heavy metals than others **(Singh et al., 2010a).** The data also, declared that the plants content of heavy metals and micronutrients exceeded (in most cases) the permissible limits recorded by Standard limit according to **Bennett (1993); Adriano (1986); Misra and Mani (1991), Brady (1984),** Normal range in plants according to **Hajar et al., (2014)** and Maximum permit limit of elements (mg/Kg) in vegetables and fruits according to National Environmental protection Agency of China, **Turkdogan et al., 2003**. **Emongor and Ramolemana (2004)** recorded that heavy metals taken up by vegetables grown under irrigation with wastewater tend to remain in the roots. Only a fraction of the heavy elements are translocated to the shoots, and even a smaller fraction reaches the fruit.

Table 4. Some physical characteristics and macronutrients content of the studied soil

Profiles No.	Depth cm	EC dS/m	pH	SP	Cation meq/l				Anion meq/l			
					Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{-}	HCO_3^{-}	Cl^{-}	SO_4^{-}
Parsley	**0-30**	1.32	7.44	30	4.63	3.49	4.68	0.35	0	5.55	4.55	3.05
	30-60	0.97	7.36	25	4.63	1.19	3.66	0.31	0	3.33	3.64	2.82
Tomato	**0-30**	1.78	7.6	30	7.72	4.89	3.3	0.35	0	2.4	2.73	6.13
	30-60	1.16	7.72	32	6.18	1.61	2.95	0.26	0	2.4	3.64	4.96
Pepper	**0-30**	1.63	7.54	37	3.69	5.43	6.28	0.25	0	3.3	6.1	6.25
	30-60	1.27	7.43	34	4.12	4.13	3.66	0.33	0	1.85	2.73	7.66
Pumpkin	**0-30**	1.39	7.39	35	3.69	3.83	3.53	0.39	0	2.77	2.82	7.85
	30-60	0.87	7.48	26	5.15	0.19	2.67	0.25	0	2.96	2.73	2.57
Jew's mallow	**0-30**	1.41	7.56	30	4.63	2.64	5.85	0.39	0	4.44	3.64	5.43
	30-60	1.19	7.66	27	5.15	2.6	3.24	0.33	0	1.66	2.73	6.39
Cucumber	**0-30**	0.89	7.48	28	4.12	2.22	2.23	0.27	0	2.4	1.82	4.62
	30-60	0.87	7.63	27	2.57	2.76	2.78	0.20	0	3.7	3.64	0.97
Virgin soil (control)	**0-30**	3.48	7.53	27	13.59	8.4	11.97	0.96	0	1.02	12.07	21.83
Mean of soil profiles		1.3	7.5	31.66	4.45	3.75	4.31	0.33	0	3.48	3.61	5.56
LSD at 0.05		**0.37**			**1.77**	**1.46**	**1.83**	**0.09**		**1.47**	**1.78**	**1.92**
Virgin soil (control)	**30-60**	4.9	7.65	27	15.78	7.11	23.96	1.72	0	1.75	24.22	22.61
Mean of soil profiles		1.06	7.55	28.5	4.63	2.08	3.16	0.28	0	2.65	3.19	4.05
LSD at 0.05		**0.21**			**1.46**	**1.6**	**0.58**	**0.14**		**0.95 (n.s.)**	**o.75**	**2.68**
Soil profile 0-30 (ppm)					**89.17**	**45.6**	**99.13**	**12.90**	0	**212.62**	**128.01**	**267.o4**
Soil profile 30-60 (ppm)					**92.78**	**25.29**	**72.68**	**10.94**	0	**161.91**	**113.11**	**194.52**
Indian standard (1983) and Awashthi (2000) mg/ Kg^{-1}					**0-3500**	**0-500**	**0-300**	**0-450**	-	-	-	**0-45**

Table 5. Heavy metal concentration (ppm) in soils of El - Gabal El - Asfar farm compared with a maximum permissible limits

site	Plant	Depth (cm)	Cd	Co	Ni	Pb	Fe	Zn	Cu	Mn
1	**Parsley**	0-30	0.05	0.1	0.2	2.38	29.91	27.6	1.52	3.43
		30-60	n.d.	0.02	0.1	2.14	28.31	25.5	2.34	2.46
	Tomato	0-30	0.04	0.1	0.22	2.76	29.96	31.4	1.64	3.74
		30-60	0.03	n.d.	0.1	1.53	27.18	24.0	0.96	3.62
2	**Pepper**	0-30	0.1	0.11	0.85	5.76	50.56	28.12	4.26	4.89
		30-60	0.02	0.03	0.72	5.22	50.81	27.23	3.12	3.46
	Pumpkin	0-30	0.05	0.1	0.89	6.02	49.32	28.43	4.72	4.95
		30-60	0.01	n.d.	0.65	5.34	41.14	27.11	3.46	4.73
	Molokhia	0-30	0.1	0.1	0.85	5.62	51.08	30.52	4.52	5.16
		30-60	n.d.	0.02	0.82	5.54	50.16	29.18	3.86	5.08
3	**Cucumber**	0-30	0.11	0.11	0.76	4.33	45.02	34.17	3.34	5.41
		30-60	0.03	0.01	0.71	4.01	42.19	33.2	3.14	6.11
The mean		0-30	0.075	0.1	0.62	4.48	42.64	30.04	3.33	4.59
		30-60	0.015	0.01	0.51	3.96	39.96	27.70	2.81	4.24
Virgin		0-30	0.03	0.002	0.67	0.52	4.25	0.93	0.47	3.77
		30-60	0.03	n.d.	0.56	0.24	3.98	0.97	0.39	3.11
Indian standards (1983) and Awashthi (2000)		ppm	3-6	-	75-150	250-500	-	300-600	135-270	-
Candian (2011)		ppm	1	19	37	45	-	290	62	-
Dutch guidelines according to Cabral Pinto et al., (2015)		ppm	0.8	9	36	85	-	140	36	-

Table 6. Heavy metal concentration (ppm) in the studied plants of El- Gabal El- Asfar farm compared with Maximum permit limit

Site	Plants	Cd	Co	Ni	Pb	Fe	Zn	Cu	Mn
1	Parsley	3.2	9.2	9.9	13.1	38.3	122	182	70
	Tomato	2.8	9.6	13.9	13.3	31.1	91	174	116
2	Pepper	3.3	8.9	12.2	12.2	31.1	88	186	20
	Pumpkin	3.5	8.8	12.1	13.6	32.5	99	171	30
	Molokhia	3.2	9.1	13.2	12	29.8	24.3	119	180
3	Cucumber	3.1	8.7	12.5	12	22.2	18.8	116	30
*		0.05-1.2	0.05-0.5	0 – 4	0.1-3.0	50-250	20-50	5-20	20-300
**		-	-	0.1-1.0	-	50-250	25-150	5-20	20-200
***		2	0.1-10	0.1-3.7		640-2486	1-160	0.4-45.8	15-100
****		0.5	0.5	10	9	-	100	20	-

* Standard limit Bennett (1993), Adriano (1986) and Misra and Mani (1991) ppm ** Brady (1984), *** Normal range in plants according to Hajar et al., (2014) ppm. ****Maximum permit limit of elements (mg/Kg) in vegetables and fruits according to National Environmental protection Agency of China, Turkdogan et al. 2003

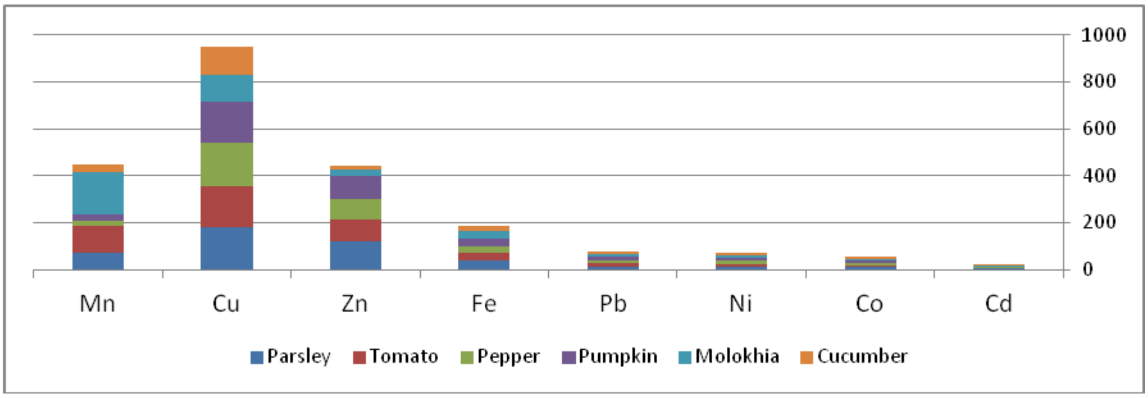

Fig 3. The plants content of heavy metals and micronutrients.

4. Conclusion and Recommendations

Based on these results, it can be concluded that proper management of wastewater irrigation and periodic monitoring of soil fertility and quality parameters are required to ensure successful and safe long term reuse of wastewater for irrigation. The long term wastewater irrigation has led to contamination of soils and food crops in the study area. The present study strongly recommended that wastewater effluent must not be used (after or before the treatment) in irrigating crops that are eaten by humans or animals, because this may lead to bioaccumulation of heavy metals that cause risks to the consumers, since dietary of food results in long- term low body accumulation of heavy metals and detrimental impact becomes apparent only after several years of consuming such food. As an alternative, because wastewater contains macronutrients it could be used in irrigation of woody species which used in wood industry or which is used for protection to soil against erosion caused by wind, particularly in arid and semi arid area.

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