Utilization of Treated Municipal Wastewater for Growing Some Aromatic Plants to Produce Volatile Oils and Study Its Nutritional Status in Arid Region

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Abstract

To avoid any contamination risk of edible crops, the safety use of treated municipal wastewater is growing industrial non- food crops such as aromatic plants to produce volatile oils for manufacturing soaps, cosmetics and perfumes, etc. Some investigators stated that aromatic plants can be grown in soils enriched with heavy metals without risk for metals transfer into the oils. Therefore, two field experiments were conducted in a sandy soil to investigate the influence of treated domestic sewage effluents or freshwater (control) on the essential oils of geranium, peppermint, fennel, marjoram, and chamomile plants. In the first experiment, the plants were irrigated with treated domestic sewage effluents, while in the second the plants irrigated with fresh water and received the chemical fertilizers. Heavy metals accumulation in plant organs and the nutrient status of plants were studied. Results indicated that the treated municipal waste water contain obvious amount of nutrients sufficiently to growing the tested crops and the plants had higher herb yield than that irrigated with fresh water. Irrigation of geranium and fennel plants with wastewater caused a significant increment in the essential oils concentration by 10.9 and 15.7 %, but lowered it in peppermint and sweet marjoram plants by 4.6 and 13.7 %, respectively. The oil yields of five crops were higher under wastewater irrigation and with geranium plants exceeded by 64.5% than that irrigated with fresh water. Uptake and accumulation of heavy metals in plant parts was varied according to element, plant specie and organ. No detectable amount of the potential toxic elements was recorded in the essential oils of the aromatic plants. From this standpoint, treated municipal waste water can be used for growing aromatic plants in the arid area to produce volatile oils without causing any reduction in quantity and quality of volatile oils.
Keywords: Treated municipal waste water; aromatic plants; heavy metal; volatile oils; nutrient status

Introduction

Irrigated agriculture in Egypt consumes about 80% of the Nile's water and almost all available conventional water resources have been exhausted (E1-Kady and E1-Shibini, 2001). The use of non-conventional water resources was reviewed, with special emphasis on the reuse of treated wastewater .Throughout the last decade; municipal wastewater reuse has emerged as an important and viable means of supplementing dwindling water supplies in a large number of regions throughout the world. Scott *et al* (2004) mentioned that sewage, often untreated, is used to irrigate 10 percent of the worlds crops , especially in urban areas, reveals the first global survey of the hidden practice of wastewater irrigation. In many instances, reuse is also promoted as a means of limiting wastewater discharges to aquatic environments. Lopez *et al* (2006) and Weber *et al* (2006) reported that the use of municipal wastewater for irrigation purposes has many profits; including the safe and low-cost treatment and disposal of wastewater, the conservation of water and recharge of groundwater reserves; and the use of nutrients in the wastewater for productive purposes. Application of treated domestic sewage effluents improves soil fertility and physical properties, causing an increase in crop yield. In this concern, Hussain and A1-Saati (1999) noticed from their experiments that the use of wastewaters in Saudi Arabia as a supplemental irrigation has not only increased crop production, water use and nitrogen use efficiencies but also served as a source of plant nutrients. It was also found that the use of wastewater can save up to 50% application of inorganic nitrogen fertilizer if the wastewater contains 40 mg N/l. In the same direction, Moscoso (1999) reported that experiments in cultivating commercial crops such as beans, broccoli, cabbage, and corn showed that the wastewater carried all the necessary nutrients for cultivation, allowing growers to save on the cost of fertilizers, which often account for over 50% of production costs. This type of use for wastewater is not only an efficient use of the water that produces food, but also generates employment and income, and expands the agricultural boundaries of desert areas. To illustrate the scope for wastewater irrigation, Morris *et al* (2003) mentioned that a city of 500,000 people each using 200 l/d would produce about 30 x 106 m^3/year of wastewater, assuming 85% was collected by the municipal sewage system. If the treated wastewater were used at a reasonably efficient rate of 5000 m^3/ha/year, then some 6000 ha could be irrigated. Further, with typical nutrient concentrations of 50 mg/l N, 10 mg/l P and 30 mg/l K in wastewater, all of the nitrogen and most of the phosphorus and potassium normally required for crop production would be supplied by the effluent. In addition, Rattan *et al* (2005) and Toze, (2006) stated that municipal wastewater besides being source of irrigation water, these wastewaters contain appreciable amounts of plant nutrients. There is potential for these nutrients present in recycled water to be used as a fertilizer source when the water is recycled as an irrigation source for agriculture. On the other side, crops raised on the metal-contaminated soils accumulate metals in quantities excessive enough to cause clinical problems both to animals and human beings consuming these metal rich plants (Tiller, 1986). Also, Salgot *et al* (2006) reported that is chemicals in low concentrations may show no direct toxic effects but do show long-term chronic effects or bioaccumulation. However, Rattan *et al* (2005) reported that risk assessment in respect of metal contents in some vegetable crops grown on these sewage-irrigated soils indicated that these vegetables can be consumed safely by human. On the contrary, Ying *et al* (2005) demonstrated that effluents after biological treatment still contain heavy metals and persistent organic contaminants. The persistent organic contaminants accumulated in soil may transfer through the food chains and cause adverse health effects on human or biological effects on soil fauna and flora after long-term application. To avoiding the hazard from food contamination under using treated domestic sewage effluents for crop irrigation, its recommended to using the low quality wastewater for growing fiber or oil crops (Saber *et al*, 2002, Angelova *et al*, 2004 and Hussein *et al*, 2004), where the oil extracted from these plants contain less or free from heavy metals, or for cultivation of cut flowers such as roses (Nirit *et al*, 2006) or for growing aromatic plants (Zheljazkov and Nielsen 1996 and Zheljazkov & Warman 2004) Aromatic plants are one of the most important source for increasing the economy of agriculture of many countries and may prove to be useful in small scale industrial or arable crop for Egyptian farmers, particularly in newly reclaimed soils (Khalil *et al,* 2001).Plants differed in their uptake and distribution and accumulation of minerals in their organs according to metals, plant species and plant parts (Guo *et al* 1999 and Barman *et al* 2000).

Therefore, the present study was conducted to investigate : 1) the effect of treated municipal wastewater (TMW)on the quantity and quality of the essential oil for five aromatic plants , 2) evaluation of TMW as a nutritional source for the tested plants and study its nutritional status , 3) content and distribution of minerals an plant parts of tested plants and 4) the possibility of using TMW for growing fennel, peppermint, marjoram, geranium and chamomile plants to produce volatile oils in arid region**.**

Materials and Methods

In the present work two field experiments were conducted during 2005 and 2006 in a sandy soil in western Giza (Abourwash district), Egypt to investigate the effect of using partially treated municipal sewage effluents or freshwater (Mansorea canal taken from river Nile) as control on the quantity and quality of the essential oil of five aromatic plants *i.e.*, sweet marjoram (*Majorana hortensis*, L), peppermint (*Mentha pipperita* L.) , geranium (*Pelargonium graveolens*, L.), fennel (*Foeniculum vulgaris*, L.) , and chamomile(*Matricaria chamomilla*, L.). Plant material used in this study consisted of seeds of fennel, uniform seedlings of chamomile and sweet marjoram, uniform stem cuttings of peppermint and terminal cuttings of geranium were kindly supplied from the Experimental Station of Pharm. Sci. Dept. at Giza, Egypt. Seeds, cuttings, or seedlings were planted in the field at the recommended sowing date for each plant specie, in hills 30 cm apart on rows 70 cm width. Each experimental unit area was 21m^2 (6 m long x 3.5 m width, included 5 ridges). Under TMW irrigation, plants grown without any supplementations of chemical fertilizers before and during the growth season, while under fresh water irrigation (control) the plants were fertilized with the recommended fertilizers rates of NPK for the five plant species. Where, calcium super phosphate was added before the cultivation. While, ammonium sulphate and potassium sulphate were divided into two split up doses. The first portion was added after one month from cultivation, the other one was added after one month later. After each cutting, a dose from N and K fertilizers were applied to peppermint, geranium, and marjoram plots as recommended by Ministry of Agriculture in Egypt. The experiment was arranged in a split – plots, where the water irrigation type was occupied in the main plots, while the plant species were located in sub- plots, with four replicates. One could be said that every plant species carried out in a separate unit, and the experimental plots included two treatments, which were the comparison between irrigation with treated municipal wastewater (TMW) and fresh water (FW). The seedlings were thinned and the healthy plant was left. All agricultural practices needed for growing healthy plants in sandy soils were conducted as recommended. Wastewater and conventional water samples were collected on every watering and analyzed according to standard methods (Eaton *et al*, 1995). Soil samples at (0 – 30 cm depths were taken from each plot after crop harvest,. They were analyzed for pH, EC, TSS, N, P, K, Ca, Mg, Na, Fe, Mn, Zn, Cu, Cd, Ni, and Pb according to standard procedures (Sparks, 1996). The three crops were irrigated when the soil water deficit in the root zone and plant apparatus. Seasonal water volume applied during the experimentation ranged from about 5000 to 15000 m^3 /acre according to the plant growth period. The plant herbage was harvested by cutting above 10 cm over the soil surface and plant growth characters in terms of plant height, number of branches/ plant, and herbage fresh weight were recorded. Total seed flower heads or herbage yield / acre for the tested plants were taken from the whole plot after harvest. At the second cut or before pluming , 5 plants were taken and divided to roots and herb and each part subjected to nutrient and heavy metal contents determination in the laboratories of the project "Micronutrients and other Plant Nutrition Problems in Egypt" (NRC/GTZ). Oil content was determined by distilling a representative herb, heads or umbels sample per replication in Clevenger's apparatus. Each sample was separately subjected to hydro-distillation in order to determine the percentage of essential oil according to the Egyptian Pharmacopoeia (1984). The oil yield per acre was calculated for each plant specie. The resulted essential oil from each treatment was dehydrated over anhydrous sodium sulfate, and then subjected to GLC analysis with Varian VISTA 6000 FID model. The separation was carried out with 2 m x 1/8″ stainless steel, 3 % OV-101 Column. The flow rate of the carrier gas (nitrogen) was maintained at 50 ml / min. The Column temperature was programmed from 80° to 200° C at the rate of 4° C / min. The injection port temperature was maintained at 180° C and detector at 240° C. The relative percentage of each compound was determined by Varian 4270 integrator. The identification of the essential oil constituents was accomplished by comparing retention times of the peaks with those of reference compounds run under identical conditions. More conformation was carried out by injection of the authentic samples with the oil samples. Data obtained (mean value of two growing seasons), were subjected to standard analysis of variance procedure. The values of L.S.D were calculated at 5 % level according to Snedecor and Cochran (1980).

Results and Discussion

1. Water and soil criteria:

As shown in Table (1a) the soil physical and chemical properties, the texture of the two soils are sandy soils, which will allow the greatest rates of water per percolation, but the least adsorption and siving action (Emonogor & Ramolemana, 2004). The use of treated municipal wastewater (TMW) for irrigation aromatic plants (geranium, peppermint, marjoram, chamomile and fennel) caused a slight increase of some parameters of soil (0-30 cm), where the pH was reduced from 8.3 to 7.9. Similar findings were observed by Rattan *et al* (2005) who mentioned that the soil pH dropped by 0.4 unit as a result of sewage irrigation. Data also indicated that the concentrations of N, P, Fe, Zn, and Cu are much higher in the soil irrigated with TMW than those irrigated with freshwater (FW), while there was no significant variation in Cd, Ni and Pb concentrations between the two sources of irrigation water. According to Pescod

(1992) threshold values of heavy metals in irrigation water leading to crop damage are 2000 mg/l for Zn, 200 mg/l for Cu, 5000 mg/l for Fe, 200 mg/ l for Mn, 200 mg/l for Ni, 5000 mg/l/l for Pb and 10 mg/l for Cd. It is worthy to mention that all parameters of soil and water are within the permissible limits according to WHO, 1989 guidelines. All the pH of the wastewater effluent samples is within the permissible limit. These values of pH are suitable for growing most plants, where the tolerance limit of pH for irrigation water ranged from 6.0 to 9.0 (Rattan *et al*, 2005).

Table (1 a): Soil properties (at harvest time) as affected by the two water irrigation types

Characters	Sand %	Silt %	Clay %	Texture	pH	EC mmhos/cm	HCO_3	Organic mater %	Concentration (mg/100g)						Concentration (ppm)						
									N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu	Pb	Cd	Ni
Freshwater	92.8	-	5.2	Sandy	8.38	1.51	2.4	0.17	32.2	0.50	9.88	176	8.06	66.24	3.4	5.8	1.5	0.3	0.4	T.	1.2
Treated wastewater	90.8	-	7.2	Sandy	7.9	0.39	2.0	0.34	114.8	0.85	11.78	90	8.14	9.57	30.3	7.0	77.9	7.0	0.6	0.1	1.6

Table (1b): The properties of the two water irrigation types

Characters	pH	EC mmhos /cm	TSS mg/l	Concentration (%)						Concentration (ppm)						
				N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu	Cd	Ni	Pb
Freshwater	7.35	1.190	000	0.6	0.1	2.68	3.67	0.56	130.2	1.11	0.05	0.09	0.02	0.003	0.04	0.008
Treated wastewater	8.30	1.224	712	16.9	0.4	4.18	1.7	0.53	121.7	4.20	0.22	0.7	0.18	0.004	0.04	0.009
Permissible levels*	6- 9		2000	-	-	-	-	-	150	5.00	0.20	2.00	0.20	0.01	0.20	5.000

According to WHO, 1989.

2. Nutrient status

It is clear from Table (1b) that the concentration of almost all the nutrient elements tended to be higher in sewage effluents. Among these plant nutrients, sewage effluents contained appreciable amounts of useful major plant nutrients, about 28 and 4 and 1.6 times more N, P and K, respectively compared to fresh water irrigation as shown in Table (1b) , which was also reflected in the appreciable build-up of these nutrients in sewage-irrigated soils of this study area and in parts of tested plants. In addition, sewage effluents contained sufficient amounts of micro- nutrients amounted by 9.8, 4.4, 2.9 and 9.0 times higher amounts of Fe, Mn, Zn and Cu, respectively compared to freshwater(from canal). Similar results were noticed by Yadav *et al* (2002) and Rattan *et al* (2005). Although sewage effluents had elevated concentrations of some of the metals compared to freshwater, the concentrations of these metals in these two sources of irrigation water were within the permissible limits for their use as irrigation water. There were no appreciable variations between these two sources of irrigation water in respect of Cd, Ni and Pb. Taking into account the chemical analyses of the treated wastewater, the amount of mineral elements distributed by irrigation satisfied the plant nutrient requirements, where the calculated amounts of N, P, K were 253.5, 60.0 and 62.7 kg/acre (Table, 2) and this amount recovery the requirement of the 5 tested plants according to Abouzied (1992). In addition, sewage effluents contained the appreciable amounts of micro-nutrients, which play an important role in enhancement the plant growth (Khalifa, 2005) and the content of volatile oils of aromatic plants (El-Sherbeny & Abou-zied ,1986). It could be concluded from the above results that the treated municipal waste water contain obvious amount of nutrients sufficiently to growing the tested crops and the plants had higher herb yield than that irrigated with fresh water. These results mean that it can use TMW for growing some aromatic plants without addition of chemical fertilizers, consequently save the fertilization costs. In this regard**,** Moscoso(1999**)** found that using TMW for cultivation commercial crops allowing growers to save cost of fertilizers, which often account for over 50% of production costs.

3 a. Distribution of Nutrient and heavy metals in plant parts

Results in Table (3) indicated that the concentrations of Cd, Ni and Pb in herb were higher of most aromatic plants than in their roots. Similar finding was reported by

Table (2): Comparison between mineral elements requirements for five tested crops and nutrients carried by effluents of treated municipal wastewater.

Mineral elements	Plant requirements (kg / acre)*					Nutrients carried by TMW (kg/acre/ year)[1]
	Marjoram	Peppermint	Geranium	Fennel	Chamomile	
N	93.0	186.o	186.o	62.0	93.0	253.5
P	62.0	46.5	46.5	46.5	62.0	60.0
K	48.0	24.0	24.0	24.0	48.0	62.7

[1]The amount of water irrigation 15000 m^3/ acre/ year according to Saber *et al*(2001).
* A ccording to El-Sherbeny & Abou-zied (1986) and Abou-zied (1992).

Rossens *et al* (2002). More or less the concentrations of plant nutrients and heavy metals in the plant parts of plants irrigated with FW are similar to those irrigated with TMW. In comparison between plant species, the data indicated that concentration of Ni, Cd and Pb were higher in roots of peppermint, geranium and fennel plants, respectively than other plant species. While roots of chamomile contain more Cu, Fe and Zn elements than other plant species. Concerning the concentration of minerals in herbage, data in Table (3) showed that the herb of peppermint contained more Ni and Pb, while chamomile contain more Fe than other plants. It can be concluded that the uptake and accumulation of heavy metals in plant parts was varied according to element, plant specie and organ. Barman *et al* (2000) came to the same conclusion. The low concentrations of potential toxic elements in roots and herb of the 5 tested crops can be attributed not only to low concentrations in the water irrigation, but also to their unavailability due to the high pH and the increase of organic mater in the medium textured soil (Mantovi *et al*,2005). Zheljazkov *et al* (1996) mentioned that plant-heavy metal concentrations of medicinal plants varied in accordance with their concentrations in the soils. Hussain, & Al-Saati (1999) demonstrated that wastewater irrigation did not increase the concentrations of plant nutrient elements and the heavy metals in corn and sorghum plants to hazardous limits according to the established standards and could safely be used for crop irrigation. The increase in concentration of nutrients in TMW irrigation caused an increase in photosynthesis processes, which can be observed in the increase of dry weight of plant biomass. A similar pattern was also noticed in case of volatile oils production. This indicated that the aromatic plants were not only tolerant to TMW irrigation but its presence stimulated biomass production. Mantovi *et al(*2005) and Nirit *et al* (2006) reported that tissue contents of all the analyzed macronutrients were found to be in the range accepted as appropriate for proper plant function. Rattan *et al* (2005) indicated that sewage effluents contained much higher amount of P, K, S, Zn, Cu, Fe, Mn and Ni compared to groundwater. While, there was no significant variation in Pb and Cd concentrations in these two sources of irrigation water and metal content were within the permissible limits for its use as irrigation water. It is worthy to stated that the concentration of minerals in plant parts of 5 aromatic plants were within the range of element concentrations in medicinal plants according to Sheded *et al*(2006) and below the permissible critical levels (WHO, 1989).

Table (3): Plant nutrients and heavy metals contents in some aromatic plants irrigated with fresh water and treated sewage effluents

Elements		Geranium				Peppermint				Marjoram				Chamomile				Fennel			
		Root		Herb		Root		Herb		Root		Herb		Root		Herb		Root		Herb	
		FW	MW	FW	MW	FW	MW	FW	MW	FW	MW	FW	MW	FW	MW	FW	MW	FW	MW	FW	MW
N	%	0.82	0.88	1.21	1.28	0.69	0.55	2.23	2.30	0.84	1.32	1.97	1.97	-	0.46	-	1.97	0.35	0.58	0.77	0.88
P		0.13	0.12	0.19	0.12	0.17	0.20	0.31	0.27	0.15	0.11	0.26	0.21	-	0.308	-	0.303	0.37	0.29	0.27	0.31
K%		0.76	1.2	2.47	1.12	1.14	1.66	2.51	2.85	0.70	0.91	2.51	2.47	-	1.68	-	3.08	2.48	2.20	2.79	3.15
Ca		0.46	0.68	1.32	0.72	0.22	0.20	0.44	0.52	0.22	012	0.52	0.40	-	0.26	-	0.46	0.13	0.22	0.72	1.36
Mg		0.005	0.004	0.005	0.005	0.005	0.005	0.005	0.005	0.004	0.004	0.005	0.005	-	0.004	-	0.005	0.055	0.004	0.006	0.004
Na		0.294	0.552	0.64	0.30	0.29	0.35	0.24	0.29	0.260	0.13	0.11	0.19	-	0.68	-	0.52	0.35	035	0.38	0.39
Fe	ppm	326	143	280	329	354	337	356	335	32.8	86.1	324	327	-	692	-	222	345	225	212	185
Mn		42.4	22.6	39.4	31.2	62.2	24.2	70.9	40.3	38.8	22.4	49.4	33.7	-	16.9	-	28.1	24.5	15.3	16.7	17.2
Zn		25.3	42.1	29.5	28.1	19.4	46.2	28.0	33.2	12.2	16.0	31.2	31.7	-	43.4	-	42.3	17.7	14.3	38.3	27.6
Cu		8.9	9.6	8.1	7.17	16.9	15.4	16.9	10.2	15.8	14.5	12.8	11.9	-	22.1	-	20.7	13.4	11.5	11.5	7.16
Cd		0..92	0.76	1.0	0.74	0.76	0.67	0.84	0.80	0.72	052	0.88	0.92	-	0.64	-	0.76	0.27	0.76	0.27	0.6
Ni		3.92	3.52	4.0	4.49	4.8	3.8	5.52	3.96	3.16	1.6	5.04	3.92	-	4.64	-	4.24	3.63	2.08	3.86	3.4
Pb		1.68	1.96	2.16	1.90	1.84	1.53	2.88	2.36	1.28	0.84	2.12	1.92	-	1.96	-	1.92	2.46	1.44	2.69	2.12

FW: Fresh water MW: Treated municipal waste water

Table (4): Heavy metal content in the five aromatic plants as affected by two irrigation types.

Metal / plant	Concentration(µg/g)					
	Cd		Ni		Pb	
	FW	TMW	FW	TMW	FW	TMW
Geranium	0.96	0.73	3.96	3.92	1.91	1.89
Peppermint	0.83	0.78	5.39	3.93	2.70	2.21
Marjoram	0.83	0.78	4.37	3.09	1.80	1.53
Fennel	0.27	0.65	3.78	3.00	2.61	1.91
	Accumulation (mg/plant)					
Geranium	0.159	0.184	0.657	0.980	0.317	0.472
Peppermint	0.020	0.021	0.130	0.108	0.065	0.061
Marjoram	0.027	0.026	0.141	0.102	0.061	0.050
Fennel	0.013	0.039	0.176	0.178	0.122	0.114

FW: fresh water TMW: treated municipal wastewater

3 b. Accumulation of heavy metal in aromatic plants

As shown in Table (4) and Fig (1) fennel plants contain low concentration of Cd and Ni in comparison of other tested plants, while lead content was relatively high in the marjoram tissues. Concerning to the potential toxic elements(PTE) i.e. Cd, Ni and Pb accumulation, the data in Table(4)& Fig(1) showed genotypic variation, where geranium plants accumulated higher Cd, Ni and Pb while fennel plants accumulated the lowest Ni. Meanwhile, in most cases, there was no significant variation in the potential toxic elements accumulation in tested plants due to irrigation type and the content of all plants from these elements were remained well below the hazard limits according to Pescod (1992) and Hopke,(1996).

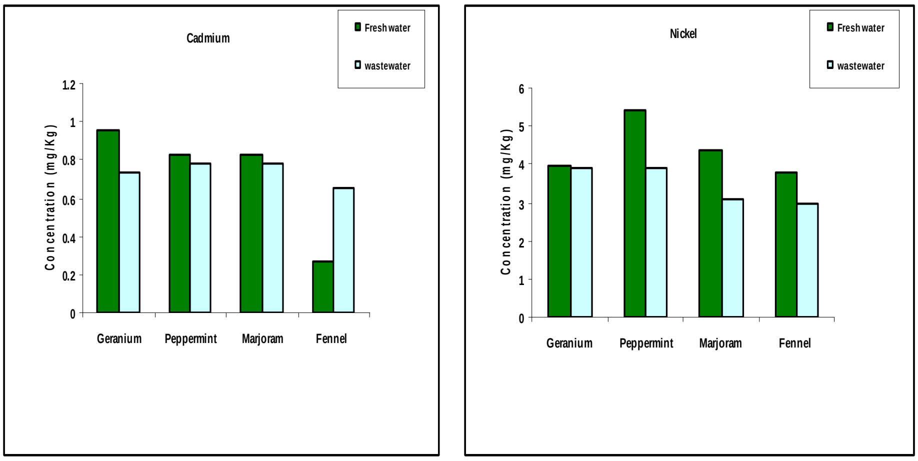
4. Herbage yield

Results presented in Table (5) indicated that plants grown under TMW irrigation produced the tallest plants, more number of branches, more root weight and consequently gave the highest herb, umbels or flower heads per acre than those irrigated with fresh water and supplemented by chemical fertilizers. These results were true with the five crops, where yields/acre of geranium, peppermint, marjoram, chamomile and fennel plants were exhibited an increase of 48.4, 18.8, 21.8, 11.9 and 10.9 % in comparison to those irrigated with fresh water, respectively. These increment may be attributed to the amount of mineral elements distributed by irrigation satisfied the tested aromatic plants nutrient requirements (Lopez *et al* 2006), improved growth characters i.e. root weight, plant height and number of branches (Table 4) and to an inferior extent the hormonal action of treated domestic sewage effluent might had a slight stimulatory role on plant growth (Krishnamoorthy, (1981). Similar increments of crops yields under irrigation with TMW were recorded by Sheikh *et al*(1987) with salad crops, Saber *et al* (2002) with cereal and winter oil crops, Hussein *et al* (2004) with summer oil crops and Lopez *et al (*2006) with olive trees.

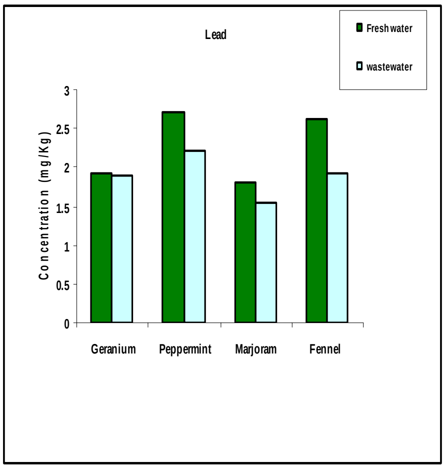
5. Volatile oil yield

It is worth to note that the volatile oils percentages of aromatic plants under TMW were much higher than that of freshwater, as presented in Table(4). However, plant responses to treated domestic sewage effluents application varied between species.

Irrigation of geranium and fennel plants with wastewater caused a significant increment in the essential oils concentration by 10.9 and 15.7 %, but lowered it in peppermint and sweet marjoram plants by 4.6 and 13.7 %, respectively. The increment in oil % may be attributed to the sufficient amounts of macro- and micro- nutrients and hormones present in TMW. El-Sherbeny & Abou-zied (1986) found that foliar application of micronutrients increased the volatile oils of fennel plants. Similar results were reported by Zheljazkov *et al* (2005). While**,** oil percentage of chamomile was unaffected by the water irrigation type.



Limit level in feed: Cd 1-2 Ni 150-200



Pb 30-40 mg/kg (According to Hapke, 1996)

Fig. (1): Concentration of Cd, Ni and Pb in aromatic plants as affected by two irrigation types .

Table (4): Yield criteria's of five aromatic plants as affected by as affected by types of water irrigation.

Characters	Geranium		Peppermint		Marjoram		Chamomile		Fennel	
	FW	TMW	FW	TMW	FW	TMW	FW	TMW	FW	TMW
Plant height (cm)	54.3	69.7*	43.1	52.3*	63.2	67.6	40.7	40.1	224.5	228.4
No. of branches /plant	9.8	11.2*	15.4	16.2*	15.9	16.0	10.5	13.0*	39.3	40.1
No. of flower heads or umbels / plant							55.6	63.9*	28.0	34.4*
Roots (g / plant)	285.2	426.3*	13.9	16.8*	38.0	39.2	9.3	14.6*	51.5	60.7*
Herb fresh weight(g/plant)*	535.0	815.7*	133.0	149.9*	138.3	140.7	41.1	49.7*	206.9	275.4*
Oil %	0.193	0.214*	0.550	0.525	0.590	0.509*	0.587	0.589	1.431	1.655*
Total of herb ,heads, umbels or seeds yield (kg/acre)	17.369	25.766*	3..99	4.74*	3..960	4.825*	0.783	0.876*	0.971	1. 077*
Oil yield (l /acre)	33.522	55.140*	21.95	24.89*	23.36	24.56	4.596	5.160*	13.89	17.082*

FW: Fresh water T MW: Treated municipal waste water *Significant at 5% level
*The 2nd cut.

Concerning the oil yield per acre, the results illustrated in Table (4) indicated clearly that the oil yield of five plants were higher under wastewater irrigation and with geranium plants exceeded by 64.5% than that irrigated with fresh water. Plants irrigated with TMW without any supplementation of chemical fertilizers exhibited an increment of oil yield per unit area amounted by 4.9, 12.3 and 20.9 % for peppermint, chamomile and fennel plants relative to those irrigated with fresh water, respectively. These increment may be attributed to the heaviest herb or flower heads or seeds yield/acre produced by these plants and to the increase in the oil percentage of these plants under MWW irrigation. Similar results were reported by Saber *et al (*2002) and Hussein *et al* (2004). On the other hand oil yield/ acre of marjoram plants irrigated with TMW was less than those of those irrigated with fresh water by 3.1 %. This decrement attributed to the depression of volatile oil (%) for this plant, however it produced more herb yield/ acre. Zheljazkov *et al* (1996) reported similar results.

6. Quality of essential oil:

6 a. Chemical constituents

The relative percentage of the main constituents of the volatile oil of fresh and municipal sewage water treatments are shown in Table (5). Citronellol and geraniol were found to be the major compound in the two treatments with little slight difference, also isomenthone, geranyl butyrate, geranyl tiglate, β –pinene, myrcene and γ – terpinene as minor components had the same trend. The percentage of limonene, 1, 8-cineole, linalool carvone and eugenol were increased as affected by sewage water treatment, while citronyllyl formate was increased more than two time in plants irrigated with fresh water. The maximum percent of citronellol was observed with fresh water irrigated plant, but in comparison between FW and TMW clearly indicates the superiority of sewage water in case of citronellol / geraniol ratio that exceed than 5%.

From the foregoing results, it can be recommended to use recycling water as workable treatment for obtaining good herb of high volatile oil and good quality without any risk. Our results are agree with those of Scora and Chang (1997) who did not fined variation in peppermint oil constituents due to elevated concentration of heavy metals in the medium. In the same line, Zheljazkov et al, (2005) mentioned that peppermint, basil, and dill can be grown in soils enriched with Cd, Pb, and Cu medium without risk for metal transfer into the oils, and without significant alteration of essential oil composition that may impair marketability. They added that results support the use of aromatic plants as alternative crops for Cd, Pb, and Cu enriched soil.

Table (5): The main constituents of the essential oil composition of Pelargonium grevulinus L. plants in the second cut due to irrigated with fresh or treated municipal wastewater.

Treatments / Component	*Fresh water*	Treated municipal wastewater
α –pinene	1.26	0.43
β –pinene	0.42	0.59
Myrcene	0.72	0.68
limonene	0.43	1.07
1,8-cineole	0.3	3.69
γ –terpinene	0.97	0.44
Linalool	2.24	9.22
isomenthone	5.26	6.02
Citronellol	29.33	27.74
Geraniol	19.32	17.33
Carvone	1.06	2.3
citronyllyl formate	11.27	3.43
Geranyl butyrate	5.88	6.03
geranyl tiglate	2.8	1.67
Eugenol	1.03	3.22
Total identified	82.29	83.86

6 b. Heavy metal

Cadmium, nickel and lead contents in the volatile oils of the 5 aromatic plants under study, were below the analytical detection limits hence no data were reported. This study confirmed previous results of Yadav *et al* (2002), Angelova *et al* (2004), Zheljazkov & Warman (2004) and Zheljazkov *et al* (2005). We hypothesize that, in practice, if plants grown with partial municipal wastewater and produced volatile oils free from the potential toxic elements, consequently legally it will produce volatile oils free from the potential toxic elements and more pronounced when irrigated with secondary, tertiary or biological sewage water effluents conditions. Zheljazkov *et al* (2005) stated that peppermint, basil, and dill can be grown in soils enriched with Cd, Pb, and Cu medium without risk for metal transfer into the oils, and without significant alteration of essential oil composition that may impair marketability. Our results support the use of aromatic plants as alternative crops for Cd, Pb, and Cu enriched soils. In this regard, Sheikh *et al (*1987) stated that heavy metals are easily and efficiently removed during common treatment processes and the majority of heavy metal concentrations in raw sewage end up in the biosolid fraction of the treatment process with very low heavy metal concentrations present in the treated effluents. Thus, heavy metals are of little concern for irrigation of crops when using treated effluents as a source of recycled water. In the same direction, Toze (2006) demonstrated that Heavy metals that are present in effluents used for irrigation tend to accumulate in the soils where there is a potential that they could become bioavailable for crops. Rattan *et al (*2005) reported that although sewage effluent-irrigated soils exhibited much higher amount of DTPA-Fe, it was not reflected in Fe content of rice grain.

Conclusion

No detectable amount of the potential toxic elements was recorded in the essential oils of the aromatic plants. From this stand point, treated municipal waste water can be used for growing aromatic plants in the arid area to produce volatile oils without causing any reduction in quantity and quality of volatile oils. Though the study confirms that the domestic sewage can effectively increase water resource for irrigation but there is a need for continuous monitoring of the concentrations of potentially toxic elements in soil, plants and ground water.

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استخدام مياه الصرف الصحي المعالجـــــة لزراعة بعض النباتات العطرية لإنتاج زيوت طياره ودراسة حالتها الغذائية في الأراضي الجافة

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المركز القومى للبحوث – القاهرة – مصر

تتصف المناطق الجافة وشبه الجافة بندرة المياه , لذا فإنها تلجأ للاستفادة بمياه الصرف الصحي المعالجة في الري. ولتفادى أي مخاطر تلوث للمنتجات الغذائية, فان الاستخدام الآمن لها هو زراعة نباتات تصنيعية غـــير غذائية مثل زراعة النباتات العطرية لإنتاج زيوت طيارة. وقد أشارت بعض الأبحاث إلى أن النباتات العطرية الـــتي زرعت بأرض ملوثة بالمعادن الثقيلة لم تنتقل تلك العناصر إلى الزيت الطيار. وعلية فقد اجريت تجربتان حقليتان في أرض رملية لتقييم زراعة بعض النباتات العطرية تحت ظروف الري بمياه الصرف الـــصحي المعالجـــة ومقارنتـــها بمثيلاتها التي تروي بمياه عذبة . تم زراعة خمس نباتات عطريه هي العتر , النعناع , الشمر , البردقوش , و البابونج و لم يضف لها أي أسمده كيماوية ورويت بمياه الصرف الصحي المعالجة , في حين تم إضافة الأسمـــدة الكيماويـــة لمثيلاتها التي رويت بمياه عذبة .وتشير النتائج إلى احتواء مياه الصرف الصحي المعالجة على تركيزات من العناصـــر الكبرى والصغرى بدرجة واضحة كفت احتياجات النباتات الغذائية, حيث تفوقت جميع النباتات التي رويت بمياه الصرف الصحي في محصول العشب عن تلك التي رويت بمياه عذبة وسمدت كيماويا. نتيجة للري بمياه الـــصرف الصحي حدثت زيادة في نسبة الزيت لنباتي العتر والشمر بمقدار 10.9 , 15.7 % في حين قلت نسبة الزيـــت لنباتي النعناع و البردقوش بنسبة 4.6 , 13.7 % على التوالي, بينما لم تتأثر نسبة الزيت في أزهـــار البـــابونج. حققت جميع النباتات التي رويت بمياه الصرف الصحي المعالجة محصولا أعلى من الزيوت الطيارة عن تلـــك الـــتي رويت بمياه عذبة, حيث وصلت الزيادة مع نبات العتر إلى 64.5 %. تباينت المحاصـــيل في توزيـــع العناصـــر بأجزائها المختلفة تبعا للعنصر ونوع وأجزاء النبات. أظهرت التحاليل الكيماوية للزيت العطري المستخلص عـــدم ظهور المعادن الثقيلة بها, كما لم تؤثر نوعية المياه سلبا على جودة الزيوت الطيارة. وبناء عليه نوصى باســـتخدام مياه الصرف الصحي المعالجة في زراعة النباتات العطرية بالمناطق الجافة وشبه الجافة لإنتاج زيوت طيارة تـــستخدم في صناعة الصابون ومساحيق التجميل و الروائح وغيرها.

الكلمات المفتاحية: *مياه الصرف الصحي المعالجة, النباتات العطرية, المعادن الثقيلة , الزيـــوت الطيـــارة , الاحتياجـــات الغذائية.*