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Impact of Treated Wastewater Irrigation on Soil Quality and Plant Contamination

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ABSTRACT

Seeds of jews mellow (*Corchorus Olitorius L.*) plants were sown in 21st August 2004 in plastic container filled with sandy soil. Two types of water were used potable water and treated wastewater. Potable water were collected from tap water and treated wastewater was collected from the Central Laboratory for Environmental Quality Monitoring Plants which could discharge 70 m^3 / day. The results indicated that the potable water sample was not microbially contaminated and wastewater sample showed the less contamination of FC which might recluse the risk of transmission of fecal bacterial pathogens. In addition, chemical analysis of EC, pH, Cl and heavy metals indicated there was no hazard of immediate damage compared with FAO, 1997 guidelines. Jews mellow plants irrigated by wastewater were contaminated by copper and manganese. In addition, the plants irrigated by wastewater illustrate an acceptable range with chromium, iron, nickel, lead and zinc which was higher in r than the plant irrigated with potable water but within the acceptable range. Moreover, iron, cobalt, chromium and manganese for the upper layer of soil irrigated by wastewater indicated high level which exceed the recommended max. Concentration (FAO , 1997). The rest of heavy metals concentration (copper , nickel, lead and zinc) are less then the recommended concentration.

1. Introduction

Egypt, as semi-arid country , suffers from shortages in water supply, , which require careful management for successful agricultural production. The availability of sufficient amounts of good quality water is fundamental to all biological processes, for maintenance of biodiversity and ecosystems and for primary and secondary production functions. Natural ecosystems and agriculture are by far the biggest consumers of the Earth's freshwater. Therefore, the use of treated wastewater for irrigation can show the problems such as wastewater disposal and lack of water availability in arid zones.

The increasing usage of treated wastewater effluent in recent years is an additional stage in the development of the water policy. Therefore, the increase in the amount of treated effluent usage for irrigation is due to the reallocation of potable water from the agricultural sector to the urban population, and an increase in the amount of treated wastewater effluent irrigation to orchards. The main restriction in using treated wastewater effluent for irrigation is the chemical water quality. The current water quality of some wastewater may cause damage to agriculture prior to the contamination of water sources.

In certain cases the damage may be intense, immediate and easily identifiable. In other cases the damage may develop over time in the plants and soil. Al- Lahham, (2003) suggested that the treated wastewater can be used as an alternative for irrigation of tomatoes eaten after cooking , but not for those taken as raw, provided that the effluent quality is continuously monitored to avoid contamination. Abu-sharar, (1999) showed that the jews mellow proved to be beneficial to soil quality because of its substantial removal of trace and heavy metals from soil.

Plants, by weight, are comprised of 90 to 95 percent water. Chemicals in irrigation water can impact the growth of plants, especially container-grown plants, due to their restricted root growth and the high potential for change of soilless media with relatively low buffering capacities (Brian, 1999).

The study aims to evaluate soil quality and Jews mellow (*Corchorus Olitorius L.*) plant contamination grown in containers irrigated by wastewater treatment as compared to normal potable water.

2. Materials and Methods

Seeds of jews mellow plants were sown in 21st August 2004 in plastic containers (25 cm in diameter, 25 cm in height) filled with sandy soil (gravel layer 5cm in the bottom + 10 kg sand / container). The soil physical and chemical characteristics were analyzed at Central Laboratory for Environmental Quality Monitoring (CLEQM) as shown in Table (1).

Table (1): Physical and Chemical Characteristics for The Experimental Soil.

Mechanical analysis		Water holding Capacity %	EC ds/m	Chemical characteristics							
				Soluble Anion(meq/l)				Soluble Cations(meq/l)			
Texture	%			CO_3^{--}	HCO_3^-	CL^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
Course Sand	99	Field capacity 16.2	0.43	0	1	2	2.3	1.2	1.8	1	0.3
Fine Sand	0.8	Wilting point 6.5									
Silt	0.2	Available water 4.5									
Clay	0.0										

Soil is washed by water for only the soluble fraction of contaminations (i.e soluble metals salts like sulfates, chlorides, etc.) can be easily extracted or removed. As well, acid solution (generally HCl, H_2SO_4, and HNO3) can be efficiently applied to remove metal from soils (Giuseppe, 1999).

Two types of water were used, potable water and treated wastewater. Potable water were collected from tap water and treated wastewater were collected from the Central Laboratory for Environmental Quality Monitoring Plants which could discharge 70 m^3 / day. Wastewater source is defined as domestic wastewater and chemical wastewater. Both are collected in a tank processed in the treatment plant which could contain the wastewater of the laboratories. The Plant water might be classified as secondary treatment that is recommended by USEPA, 1992 as acceptable to irrigate eaten crops. The chemical analysis of the two types of water is presented in Table (2).

Plant samples were collected on the basis of physical age of the plant, (at the midgrowth) and analyzed for heavy metals at the same lab. The experiment includes one soil type, one kind of plant and two types of water.

Time of watering was defined by weighing the containers and to calculate irrigation amount, the following equation was used (Shawkey *et al.*, 1996):

$$Q = A.W \times D.t \quad (kg)$$

Where Q = Quantity of added water (kg)

A.W = Available Water (%)

D.t = Dry weight of soil/container (kg)

Table (2): The Average Quality Characteristics of the Potable Water and Treated Wastewater.

Parameter	Unit	Potable Water	Treated Wastewater
BOD5	mg / L	0	2
COD	mg /L	0	8
TDS	mg / L	300	449
TSS	mg / L	1	10
EC	ms / cm	0.469	0.702
pH	-	7.71	7.6
Alkalinity	-	205	207.4
Total coliform	CFU / 100 ml	0	2110
Fecal coliform	CFU / 100 ml	0	840
Cl^-	mg /L	42.19	138
As	mg / L	<0.1	<0.1
Cd	mg / L	<0.1	<0.1
Co	mg /L	<0.05	<0.05
Cr	mg /L	0.0749	0.0603
Cu	mg / L	0.041	0.071
Fe	mg / L	0.083	0.159
Mn	mg /L	0.102	0.129
Mo	mg /L	-	-
Ni	mg / L	0.016	0.012
Pd	mg / L	<0.005	<0.005
Zn	mg / L	0.043	0.074

2.1- Measurements

2.1.1 Irrigation Water Analysis

Samples of potable and treated wastewater were collected at the beginning of experimental as well the methods used for the analysis which were done at CLEQM were as follows:

a) Fecal coliform: test (EC medium), and the procedures followed were as outlined in APHA (1998). Sterile 3 mm diameter metal loop was used to transfer growth from each presumptive fermentation tube showing gas to EC broth. Inoculated EC broth tubes were incubated in a water bath at 44.5 ^{0}C for 24 h. After inoculation, all EC tubes were placed in the water bath for 30 min. Water depth in the water bath incubator was maintained to immerse the tubes to the upper level of the media. Gas production with growth in an EC broth culture within 24 h or less is considered as a positive fecal coliform reaction, and MPN was calculated from the number of positive EC broth tubes.

b) Total bacterial count (spread plate method): laboratory apparatus, media-plate count agar (aerobic plate count agar), and procedures were as outlined in (APHA, 1998). Briefly, agar media was prepared by mixing 24 g agar with distilled water, sterilized in the autoclave at 121 ^{0}C for 15 min. A 15-ml of the desired medium were poured into sterile 100 x 15 Petri dishes and left to solidify. Inoculated Petri dishes were incubated at 35 ^{0}C for 48 h. After incubation at 35 ^{0}C for 48 h, colonies were counted using a Quebec colony counter, for manual counting.

c) Conductivity and TDS: were measured using Thermo Orion 230 A^{+} plus;

d) The pH value: was measured with pH – meter and the test carried out according to the (APHA, 1998).

e) BOD: was measured by using Respirometer system which determined by measuring the amount of oxygen absorbed by a sample in the presence of microorganisms in 5 days at a temperature of 20 ^{0}C.

f) COD: as a measure of organic strength contaminate water was determined by COD Vial Adapter, DR 2010.

g) Heavy metals: Water samples were analyzed for heavy metals by using Inductively Coupled Plasma (ICP).

2.1.2 Soil Sampling Measurements

Soil mechanical analysis was carried out by the international pipette method according to (Chapman and Prate, 1961) . Soil Moisture content at field capacity and wilting point was measured by the gravimetric methods, (Vogel, 1962).

Soil chemical analysis was measured for pH which was determined in 1:2.5 soil water (W/V) suspension using Thermo Orion model 230A and EC in ds/m, was measured by using the EC meter type CyberScan 510 CON. As well, soil chemical analyses were made for the paste extract to determine the soluble cations (Ca^{++}, Mg^{++}, and Na^{+}) anions ($HCO3^{-}$ and, Cl^{-}) that were analyzed in soil paste extracts as follows:

Carbonate and bicarbonate were estimated volumetrically by titration with a standard solution of sulfuric acid, using phenolphthalein and methyl orange as indicators for each element respectively. Chloride was determined with silver nitrate according to (U.S.S.L., 1954).

Calcium and magnesium were estimated by titration following the versene method using ammonium purported as an indicator for calcium and Eriochrome Blak T as an indicator for calcium and magnesium according to (U.S.S.L., 1954).

Sodium and potassium were determined photometrically by using flame photometer (JENWAY PEP7) according to (U.S.S.L., 1954).

At the end of experiment, soils under the experiment treatments in containers were divided to upper layer 0-20 cm and 20-40 cm. Samples were analyzed for chemical analysis followed the previous methods.

Sodium Absorption Ratio (SAR) was determined as shown in the following equation that defines the relation between sodium, calcium and magnesium.

$$SAR = \frac{Na^{+}}{\sqrt{(Ca^{++} + Mg^{++})/2}}$$

where Na, Ca and Mg are ionic concentrations in milliequivalents per liter.

2.1.3 Leave Analysis

Leaves are sampled in the midgrowth, washed with tap water and oven dried at 70°C until having a constant weight. After that samples were ground and 0.5 g was taken and digested (HNO_3). The samples were diluted with dionized water then transferred to 100 ml volumetric flasks (Jones, 1991) and analyzed for heavy metals by using Inductively Coupled Plasma Analysis (ICP).

3. Results and Discussion

3.1 Irrigation water examination

Results of irrigation water examination total coliform (TC) and fecal colifrom (FC) per 100 ml in the study samples collected from CLEQM Tap water showed 0 value for each TC and FC (Table 2) . According to (Levesque *et al.*, 1993) samples of drinking water containing 1 TC and 1 FC per 100 ml were considered as contaminated, therefore, the potable water samples were not contaminated. Whereas, The result of wastewater examination (Table 2) indicated that the Value of FC was (840 CFU / 100 ml) which is below the bacteriological standard of 1000 FC / 100 gm (WHO, 1989). Further more, it is believed that the use of such less contaminating irrigation water might further recluse the risk of transmission of fecal bacterial pathogens (AL-Lahham *et al.*, 2003). The Total fecal coliform result indicated that the value which was (2110 CFU/100 ml) above the recommended value by the Institution for Standards and Metrology (1995) maximum range of 1000 CFU / 100 ml in treated wastewater. Kirkham (1986) reported that pathogens may survive on the surface of a plant irrigated with wastewater, because a warm, dark, and moist place could harbor bacteria.

Chemicals usually present in wastewater are an important concern for reuse application especially for irrigation.The EC value of irrigation water: (wastewater and potable water) were 0.46 and 0.7 ms / cm, respectively. The recommended EC for interpretation of water quality for irrigation is < 0.7 ms / cm which reflect no salinity problem in the two type water.

Chloride (Cl) may be considered as one of the most common phytotoxic ions and should be determined to assess the wastewater quality suitability for irrigation. Therefore, the chloride level of water samples was (1.2) for tap water which may be classified as non restriction on use and (3.9 meq/l) for wastewater which may be classified as slight to moderate restriction on use according to FAO 1997. In addition, the heavy metals concentrations in the two types of water were low several orders of magnitude from FAO 1997 limits. Hence, there is no hazard of immediate damage FAO, 1997 limits. Also, pH for the two types of water were (7.7 and 7.6) for tap water and wastewater respectively that was in accordance with normal pH range for irrigation water which is from 6.0 to 9.0 according to USEPA, 1992. Organic waters are usually measured by biochemical oxygen demand (BOD) and chemical oxygen demand (COD). They were zero for tap water and 2 mg / l BOD and 8 mg / l COD for wastewater. USEPA Guidelines for water reuse recommended $\leq$ 30 mg / l for the utilization of wastewater.

3.2 Soil Contamination

Table (3) shows the heavy metals concentration in the experimental soils of the two types of water at two depths (20 - 40 cm). Accordingly, iron highest concentration was found with the surface layer (depth 20 cm) of the soil irrigated with wastewater. The lowest concentration was found with the lower soil layer (40 cm) for soils irrigated with potable water. Iron level in the upper layer of the soil irrigated with wastewater was higher than its level in the upper layer of the soil irrigated with potable water and the lower layer of soil with wastewater which concentrate was higher than the recommended range (FAO, 1997). Iron is not to be toxic except at high levels or when the root medium pH is ≤ 5.5 (Paparozzi, 1994).

Table (3): The Heavy Metals Concentration (mg / l) in The Experimental Soils.

Constituent	Soil depth (cm)	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pd	Zn
Potable water	20	<	<	0.005	0.070	0.028	5.012	0.130	0.005	0.022	0.283
	40	<	<	0.005	0.049	0.016	4.644	0.115	0.005	0.021	0.255
Wastewater	20	<	<	0.006	0.102	0.069	7.085	0.237	0.012	0.029	0.540
	40	<	<	0.005	0.102	0.044	5.109	0.134	0.010	0.024	0.396
Recommended		0.10	0.01	0.05	0.100	0.200	5.000	0.200	0.200	5.000	2.000

Manganese indicated high levels which slightly exceed the recommended maximum concentration for the upper layer of soil irrigated by wastewater. Whereas, its concentration were less than the recommended concentration with the soil irrigated by potable water (20-40 cm) and sub layer of soil irrigated by wastewater (40 cm). Chromium concentration was the same at two soil levels (20-40 cm) irrigated with wastewater that slightly exceed the recommended maximum concentration. Meanwhile, Cr gave level less than recommended concentration with soil irrigated by potable water at both of the two layers.

Moreover, cobalt level was the same level in the soil irrigated by both types of water at both layer which less than concentration as the recommended level (FAO, 1997). Moreover, the rest of heavy metals concentration (copper, nickel, lead and zinc) are less than the recommended maximum concentration. Mn is not to be toxic except at high levels or when the root medium pH is ≤ 5.5 (Paparozzi, 1994).

Sodium Adsorption Ratio (SAR) that reflects the permeability and aeration (water logging) problems can occur when soil effluent SAR value above 6.00. The SAR for both types of water show no problem Table (4).

In addition, chloride and bicarbonate results for the soil of both types of water at two depths indicated the degree of restriction in use were slight to moderate (Table 5) according to FAO (1997).

Table (4): Soil Analysis of the Experiment.

	Soil depth	EC ds/m	pH	SAR	Cl meq/l	HCO3 meq/l
Potable water	20	1.6	7.70	2.5	4	0.6
	40	0.24	6.5	1.3	1	0.6
Wastewater	20	2.53	7.68	2.4	4	0.4
	40	0.257	6.80	1.6	3	0.6

Generally, all soil analysis indicated that- the trend of accumulation of heavy metals, Cl^{-}, HCO^{3}, pH, EC, SAR are high in the upper layer than the lower one. Monitoring the top of soils is required only if effluent is derived from potential sources of metals (ACT, 1999).

3.3 Plant Contamination

A toxicity problem occurs within the plant itself and is not caused by water shortage. Toxicity normally results when certain ions are taken up by plants with the soil water and accumulate in the leaves during water transpiration to such an extent that the plant is damaged. Heavy metals are toxic to plant at low concentrations; the two types of irrigation water contain very low concentrations of these trace elements and are generally not a problem Table (2). The results in Table (5) declare the effect of using potable water and wastewater to irrigate jews mellow plants.

Table (5) : The Heavy Metals Concentration (mg / l)of Jews Mellow Leave Samples Obtained from The Experiment.

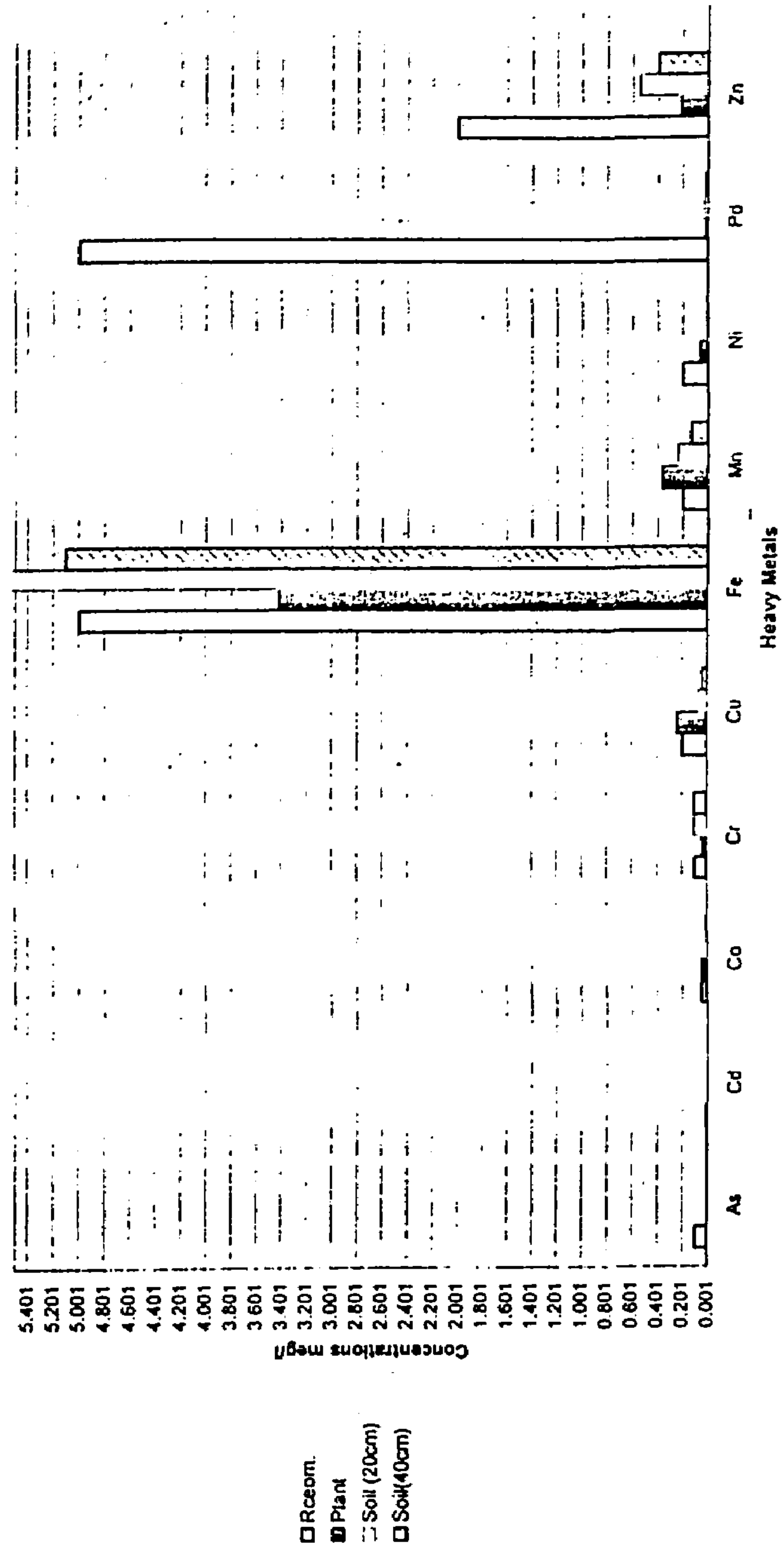
constituent	As	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pd	zn
Potable water	< 0.10	< 0010	0.05	0.023	0.123	1.420	0.191	-	0.030	0.017	0.082
Wastewater	<0.10	<0.010	0.05	0.043	0.244	3.421	0.371	-	0.072	0.023	0.219
Recommended Max. con	0.10	0.01	0.05	0.10	0.20	5.0	0.20	0.01	0.20	5.0	2

Data show that The levels of copper and manganese of the jews mellow plants irrigated with wastewater were (0.244 Cu -371 Mn) higher than the concentrations of the plants irrigated with potable water (0.123 Cu to-0.191 Mn). Also These results reflected that the concentrations of Cu and Mn are higher than the recommended maximum concentrations (0.20 Cu - 0.20 Mn) of metals for crop production (FAO,1997). The levels of copper Cu and manganese Mn are rarely a problem in the plants (Brian, 1999). Copper is toxic to a number of plants at 0.1 to 1.0 mg /l in nutrient solutions and manganese is toxic to a number of plants usually only in acid soils (Pratt, 1972). Moreover, chromium, iron, nickel, lead and zinc were higher in the jews mellow plants irrigated with wastewater than the plant irrigated with potable water but within the acceptable concentrations.

3.4 Heavy Metals concentration in plant and soil

Results illustrated in Fig. (1) show that the relation between soil and plant of heavy metals concentration were normal for Ni., Pd and Zn which indicated levels less than recommended concentrations . Meanwhile, the chromium concentration in soil irrigated by wastewater slightly exceeds the max. recommended concentration by FAO (1997 but indicated slightly at low level for jews mellow plants of the two types of waters. Copper level showed the highest level with plants irrigated by wastewater, which is higher than recommended concentration too. Also, it has normal concentration in soil for two types of water and for both depths (20 – 40). Manganese level was in the highest level for upper soil and jews mellow plants irrigated with wastewater which exceed the max recommended concentration.

Fig(1): Hevay Metals Concentration in Plant , Soil and The Max. Recommended concentrations(FAO 1997)



4. Conclusions and Recommendation

4.1 Conclusions

This study aimed at examining same quality attributes of jews mellow plants irrigated with two type of water potable water and treated wastewater. From results it can be concluded that:

1- Two types of water were used (potable water and treated wastewater) which are collected from CLEQM plants and might be classified as secondary treatment. The irrigation water examination indicated that the potable water sample was not microbially contaminated; meanwhile, the wastewater sample showed the less contamination of FC which might recluse the risk of transmission of fecal bacterial pathogens.

2- The Ec, pH, Cl^- and heavy metals indicated there was no hazard of immediate damage compared with FAO, 1997 guidelines.

3- Jews mellow plants irrigated by wastewater were contaminated by copper and manganese. Accordingly, Paparozzi, 1994 mentioned that

4- Mn in the irrigation water is not to be toxic when the root medium pH is ≤ 5.5 and Cu toxicity is uncommon.

5- In addition, chromium, iron, nickel, lead and zinc were higher in plants irrigated with wastewater than the plant irrigated with potable water but within the acceptable range.

6- Iron, cobalt, chromium and manganese content of the upper layer of soil irrigated with wastewater indicated high levels which exceed the recommended max. concentration. The rest of heavy metals concentration (copper, nickel, lead and zinc) are less than the recommended concentrations.

4.2 Recommendations

The treated wastewater can be used to irrigate jews mellow plant that are eaten cooked with a continuous monitoring of the effluent quality from treatment plant to avoid contamination. Monitoring the top of soils is required only if effluent is derived from potential sources of metals such as chemical wastewater. Monitoring of soil structural stability and/or permeability should be carried out periodically to detect deterioration. Soil pH should be monitored at suitable depth if problems of plant growth are observed.

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