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Some Chemical Properties of Soil Affected by Long-Term Application of Primary Treated Wastewater

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ABSTRACT

Effect of irrigation with primary treatedwastewater on some chemical properties of soil was the main purpose of' this investigation. Eight soil profiles were chosen fromAbou-Rawash farm (Giza Governorate)those profiles represent soils under different periods ofsewage water utilization (0, 10, 20, 25 and 50 years), respectively. The chemical analysis ofprimary treated wastewater showed that total salt concentration and heavy metal content was within the safe limits. Thus, wastewater remained within permissible limits for use as irrigation water. Soil analysis revealed that nitrogen, phosphorus and potassium content were high in primary treatedwastewater irrigated soils compared to non-wastewater irrigated soils. The soil pH and EC decreased as a result of wastewater irrigation. Data indicate that the availability of Fe, Mn, Zn and Cu in soil increased by irrigation with primary treatedwastewater compared to control soil; the highestaccumulation of micronutrients were found in the surface layer in soil irrigated with primary treated wastewater for fifty years and the lowest in the sub-surface layers of control soil. Based on our study, the concentration of heavy metals (Pb, Ni, Mo, Cd, and B) was higher in top layers of primary treatedwastewater irrigated soil compared to those not irrigated with wastewater (control soil). It has been reported that high concentration of heavy metals in primary treatedwastewater leads to an increase of their content in soil. Also, the enrichment factor of the heavy metals in soil irrigated with primary treatedwastewater were higher and taken this sequence of Ni >Pb> Cd > Mo > B.

Keywords: Enrichment factor,heavy metals,irrigation, soil properties,wastewater.

INTRODUCTION

Land and water are natural finite resources but due to indiscriminate and unscrupulous utilization, these resources are diminishing at an alarming rate. Water is becoming the most important limiting natural resources nowadays. More food has to be produced per unit of water available for agriculture and to meet the increased demand of agricultural production. Hence, it's multiple uses and re-use is becoming more and more important. However,use of wastewater as a supplemental source of irrigation is inevitable for increased agricultural production in many arid and semi-arid regions where irrigation supplies are insufficient to meet crop water needs.(Yerasi *et al.*2013)

The use of treated wastewater for agriculture has many theoretical advantages such as reduction in the consumption of high quality water (e.g., from rivers, lakes, wells) for irrigation; reduction in the amount of agricultural inputs required through the use of organic matter, P, and N from wastewater; and reduction in or even elimination of the risk of eutrophication by reducing discharge of wastewater directly into water bodies. These advantages become especially salient in semiarid climates. Essentially, a lack of water for irrigation makes usable wastewater an extremely important agricultural resource, even though it is not usually considered as a viable option. Furthermore, the nutrients present inwastewater can significantly improve the fertility of sandy soils that are commonly found in the pediplains of semiarid regions. Finally, the agricultural use of treated wastewater avoids impacts of its release in rivers with low discharge or under intermittent condition. In addition to these indicators favorable to the use of wastewater in agricultural irrigation in semiarid regions (in contrast with more humid climates), strong solar radiation on the soil greatly reduces the pathogen load that may persist in the wastewater after treatment. (Oliveira *et al.*2016).

Along with the reuse of wastewater for irrigation comes the need to understand potential environmentalimpacts of this practice. Many authors were tested the effect of municipal wastewater on soil and plant. Amin (2011) studied the effects of municipal wastewater treatments on physical and chemical properties ofsoil, showed an increase of EC, P, OM, TN, K, Na, Cl, Fe, Cd and Zn but a decrease of soil pH. In the similar way, Mohammad and Mazahreh (2003) reported a decrease of pH by the presence of high content ofammonium in wastewater. They also found an increase of soil salinity level due to the wastewater salt content.According to the others researchers, the wastewater irrigations increased soil nitrogen (N), phosphorus (P) andpotassium (K) while high levels of heavy metal build-up on the soil with the long-term use ofwastewater on irrigation (Rattan *et al.*, 2002). When the capacity of soil to retainheavy metals is reduced due to repeated use of wastewater, soil can release heavy metals into groundwater orsoil solution available for plant uptake.

The sewage water has a high fertility load; it adds availableN, P, K, Fe, Mn, Zn and Cu to soil, this indicating their significant addition through sewage suggesting use of sewage water as a low grade cheap fertilizer in agriculture. It can drastically reduce the cost due to substitution of chemical fertilizers. The concentration of heavy metals such as Cu, Pband Co in plants tissue were low compared to limits standards. These heavy metal concentrations are well below hazardous levels (Aljaloud, 2010). The effect of continuous irrigation with sewage water increases exchangeable cations to a large extent(Darvishi *et al.* 2010). Sewage water application increases the soil salinity, organiccarbon, N, K, Ca, Mg cations to a lot. Soil is a biofilter that can reduce a large part of domestic waste water pollutants, but thisfiltering increase EC, SAR, Na, Ca and Mg of soil. In additionto these, sewage water also contains significant amounts oftoxic metals such as arsenic, chromium, cadmium, copper,lead, nickel, zinc, cobalt, magnesium and iron(Ali *et al.*1996).

Our study focused on examining areas that had been subjected to long-term wastewater irrigation for different lengths of time (0, 10, 20, 25 and 50 years). In particular, we investigated the following characteristics(i)changes in pH; EC, some nutrition and the heavy metal content of soil (ii) the heavy metal and some nutrition enrichmentfactor in soil profiles.

MATERIALS AND METHODS

This studywascarried out atAbou-Rawash farm (GizaGovernorate). Table 1 shows thatparticle soil distribution of Abo-Rawash soil profiles. Table 2shows thatmetrological data of Giza station.Thestudy area is located between latitude 30° 1′ 56″ N and longitude 31° 4′ 29″ E. Eight soil profiles were done to represent somedifferent periods of irrigation using primary treatedwastewater (0, 10, 20, 25 and 50 years). The soil samples represent*(Typic Torripsamments, Sandy, siliceous, hyperthermic)*, soil taxonomy was performed according to Soil Survey Staff (2010).The soil samples were air dried, ground in a wooden pestle and mortar, and passed through a 2-mm sieve. Particle-size distribution by the pipette method described by Piper (1950).

Soluble salts and soil pH were determined according to Jackson (1973). Soluble cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}), anions (Cl^{-}, CO_3^{-2},HCO_3^{-} and SO_4^{-2}) were determined according to Black *et al.* (1965) .Available nitrogen was determined by steam - distillation procedure using MgO-Devarda alloy according to Bremner and Keency methods as described by Black *et al.* (1965). The NO_3 and NH_4 extracted with 2.0 M KCI and determination colorimetric methods according to Keeney and Nelson (1982). Available phosphorus in soilwas extraction with 0.5 M $NaHCO_3$ atpH 8.5 (Olsen *et al.*, 1954); and determined colourimetrically using the ascorbic acid method (Watanabe and Olsen, 1965). Available potassium wasextracted by 1.0 M ammonium acetate at pH 7.0 Jackson (1973) and determined by the flame photometer. Available macronutrients (N, P and K) and micronutrients (Fe, Zn, Cu and Mn) and extractable heavy metals(Ni, Cd, Mo, B and Pb) were extractable according to Soltanpour and Schwab (1977) and determined using Atomic absorption spectrophotometer.

Table 1. Effect of irrigation with primary treated waste water on particle soil distribution in Abo-Rawash soil profiles.

Depth Cm	Years	Prof. No.	Depth Cm	Coarse sand	Fine sand	Silt	Clay
				%			
1	50	1	0-20	33.3	33.0	17.3	16.4
2			20-50	41.6	43.7	9.4	5.3
3			50-100	43.8	45.9	7.6	2.7
4	50	2	0-30	29.5	30.6	21.3	18.6
5			30-45	41.3	40.9	7.3	10.5
6			45-90	44.5	45.1	6.5	3.9
7	20	3	0-15	33.1	38.7	15.3	12.9
8			15-30	36.4	33.2	14.8	15.6
9			30-60	38.9	36.9	14.7	9.5
10			60-70	39.4	41.1	11.5	8.0
11			70-100	43.5	44.2	8.5	3.8
12	50	4	0-20	24.0	32.4	24.8	18.8
13			20-60	30.6	33.4	21.5	14.5
14			60-80	37.4	42.7	13.4	6.5
15			80-100	42.0	45.7	7.9	4.4
16	25	5	0-10	32.6	36.0	16.8	14.6
17			10-50	39.9	39.8	9.3	11.0
18			50-100	43.8	44.6	8.1	3.5
19	25	6	0-40	36.6	28.6	21.5	13.3
20			40-100	45.1	44.8	6.7	3.4
21	10	7	0-25	36.4	31.1	16.3	16.2
22			25-50	41.8	33.2	9.4	15.6
23			50-100	40.5	46.9	9.0	3.6
24	0	8	0-50	44.3	46.5	5.3	3.9
25			50-100	45.6	46.0	6.4	2.0

Table 2. Metrological data of Giza station.

	January	February	March	April	may	June	July	august	September	October	November	December
Mean Monthly Max. T. °C	19.5	21.0	24.3	28.3	31.8	34.8	34.3	34.4	32.6	30.2	24.4	21.3
Mean Monthly Min. T. °C	6.4	6.7	10.2	12.1	13.3	18.9	20.2	20.4	18.6	16.0	12.3	8.3
Mean Monthly. T. °C	12.3	13.6	16.4	19.9	23.3	26.5	21.0	26.8	25.3	22.8	18.6	14.1
Mean Monthly R. Humidity in %	73	68	62	57	53	55	62	66	66	66	73	71
Mean Monthly Clowd in Octs	3.0	2.9	2.7	2.1	2.1	0.8	0.9	1.1	1.2	1.8	2.5	3.3
Mean Monthly Evaporation mmday^{-1} (Piche)	5.0	7.2	10.3	14.5	17.8	18.4	15.7	13.5	12.1	10.7	7.9	5.6
Mean Monthly Evaporation mmday^{-1} (Class A PAN)	3.3	4.5	6.4	8.5	11.2	12.8	11.1	9.7	8.5	6.9	4.5	3.3
Computed Monthly Wind Velocity 2mHight in ms^{-1}	2.0	2.1	2.4	2.4	2.7	2.9	2.7	2.1	1.9	2.2	1.9	1.8
Mean Monthly Values of Relative Duration of Bright Sun Shine in %	68	72	73	75	80	86	85	83	85	82	78	70
Mean Monthly Global Radiation in Cal Day^{-1}Cm^{-2}	275	367	443	563	620	664	647	605	531	412	311	250
Mean Monthly values of Vapor Pressure Deficit (24 Hour) in mm Hg	2.1	2.9	4.6	5.9	8.7	10.1	8.9	7.0	6.6	5.4	3.0	6.6
Mean Total Daily Solar Radiation at the Top of the Atmosphere Cal day^{-1}Cm^{-2}	306	611	745	868	946	971	960	894	799	667	540	469
Mean Monthly values of Open Evaporation After Penman(E_0) in mm day^{-1}	1.36	2.34	3.73	5.0	6.46	7.7	7.65	6.86	55.8	4.21	2.45	1.43

Enrichment Factor (EF)

EF is the relative abundance of a chemical element in a soil compared with the background(Hernandez *et al.* 2003). In this study, the EF method was used to estimate the level of possible contamination of the soil. Elements accumulation in soil amended with wastewater on a contaminated site with respect to soil on uncontaminated soil (control soil) gives the EF. The EF is calculated according to the following equationdescripted by Al-Hwaiti and Al-Khashman (2015).

EF = concentration of metals in the amended soil/concentration of metals in the control soil. The enrichment factor is used to assess soil contamination (enrichment), and its interpretation is as follows:

EF < 2 – depletion to minimal enrichment, EF <2–5 Moderate enrichment, EF <5 –20 Significant enrichment,EF <20 – 40 very high enrichment EF > 40 – extremely high enrichment. EF can also be used to evaluateelement depletion from soil.

Statistical analysis

All obtained data were subjected to the statistical analysis of correlation and regression according to Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Chemical properties of the primary treated wastewater

Some chemical properties of primary treatedwastewater were shown in Table 3. The pH of primary treated wastewater is slightly alkaline in reaction (7.55). The enhancement of pH is due to addition of various soluble salts in sewage water. The pH value of primary treated wastewater was within the permissible limits in respect of its use on agriculturallands. The salt content (EC) of wastewater (0.98 dS/m) and pH value (7.55).Both pH and EC of primary treatedwastewater are in the acceptable range based on FAO standards (FAO, 1985). The obtained values of total soluble salts (TSS) for primary treated wastewater wassuitable for irrigation waters purpose according to FAO standard which it is 2000 mg L^{-1} for water samples for irrigation.So when used this type of water, do not use the more saline waters in this class on soils with restricted drainage.The value of residual sodium carbonate (RSC) in the primary treated wastewater sample was below 1.25 meL^{-1} (safe limit for irrigation water). As for, SAR the value of (1.76) was under the limit recommended by the FAO, 1985 for irrigation water (6.0-12.0). Cation concentrations(except Mg)and anion concentration are within the permissible limit for irrigation water.Based on the results and on the standards given by FAO, 1985for using the wastewater and for discharging them on land for irrigationit may be stated that the wastewater, is less hazardous. Macro and micronutrient status and the concentrations of heavy metals of primary treatedwastewater samplearein the acceptable range based on FAO standards (FAO 1985).Nitrate content (0.0 mg L^{-1}) in the primary treated wastewater sample below the prescribed limits of 5 mg L^{-1}, also ammonium content (0.81 mg L^{-1}) was below the prescribed limits of 10 mg L^{-1}.

Table 3. Chemical analysis of primary treated wastewater from Abo Rawash health drainage station, Giza.

Parameters	Unit	primary treated wastewater	Standard Limit for Irrigation (FAO., 1985)
EC	dSm^{-1}	0.98	< 3.0
pH	Unit	7.55	6.5-8.4
Ca^{++}	mg L^{-1}	128.0	400
Mg^{++}	mg L^{-1}	72.0	60
Na^{+}	mg L^{-1}	71.3	900
K^{+}	mg L^{-1}	16.8	0.2
CO_3^{--}	mg L^{-1}	0.00	6
HCO_3^{-}	mg L^{-1}	335.5	600
Cl^{-}	mg L^{-1}	150.0	1100
SO_4^{--}	mg L^{-1}	118.1	1000
TSS	mg L^{-1}	673	2000
RSC	-	000	< 1.25
SAR	Me L^{-1}	1.76	6-12
B	mg L^{-1}	0.264	0.75
Cd	mg L^{-1}	0.004	0.01
Fe	mg L^{-1}	0.140	5
Mo	mg L^{-1}	0.023	0.01
NO_3	mg L^{-1}	0.000	5
NH_4	mg L^{-1}	0.81	10
Ni	mg L^{-1}	0.003	5
P	mg L^{-1}	0.08	2
Pb	mg L^{-1}	0.022	2

The effects of application periods with primary treated wastewater on soil properties. Data in Table4show that the pH of soil irrigated with primary treated wastewater ranged from 5.67 to 6.88 which less than the pH of soil not irrigated with wastewater (control soil) which recorded pH ranged from 7.72 to 7.83. Soil pH directly affects the life and growth of plants because it affects the availability of all nutrients in the soil. Between pH 6.0 and 6.5, most plant nutrients are in their most available statePescod, (1992). Our result agrees with Mutengu *et al.* (2007) who explained that the use of treated wastewater (TWW) for irrigation can have detrimental effects on soil quality. These include decreasing of soil pH is perhaps due to the included acidic components in wastewater which convert to acidic compounds which lead to reduction pH value.The soil pH values decreased in both surface and sub-surface layers of the soils irrigated with wastewater. The effect is more pronounce in the surface layer than in the subsurface one.Values of soil pH consider ordinarily less than 8.4 of FAO, 1985 recommendation.The electrical conductivity (EC) values in studied soil samples indicate that continuous use of wastewater in irrigation led to decrease the total soluble salts in the soil. Electrical conductivity (EC) of soil irrigated with primary treated wastewater was varied from0.54 to 1.98dSm^{-1}while the value of EC in the soil not irrigated with wastewater varied from 2.27 to 6.10dSm^{-1}.The EC explains the presence of salinity which is the most important indicator regarding to fields irrigated with wastewater. In all, these values considered slightly normal according to the limits recommended byPescod, (1992).It is obvious that EC of soil decrease with depth, this maybe due to accumulation of less soluble salts in the tope soil layer and possible formation of organic acids due to biodegradation of organic compounds (Siebe and Cifuentes, 1995). Also, using primary treated wastewater for irrigation led to increase of bicarbonate as an absolute value, while the distribution of soluble cations shows that the dominant cation is Ca^{++} followed byMg^{++}, Na^{+}, and then K^{+}.

Soil available nitrogen. According to Table 5, soil irrigated with primary treated wastewater caused an increase of nitrogen. This is in line with these findings of Rusan *et al.* (2007). Increasing the N of soil irrigated with wastewater can be attributed to the sewage water contains appreciable amount of N therefore; it brings increase in available nitrogen with different forms in the wastewater. The amount of N is more pronounce in the surface layer than in the subsurface one.

Soil available potassium. Primary treated wastewater usage caused increase of available potassium because sewage water contains appreciable amount of K therefore, it brings significant increase in available potassium. Similar findings had also been reported by Malla and Totawat (2006).Wastewater is usually an important source of K^{+}, plants need large amounts of potassium for their growth and development. Potassium applied to soil by wastewater can be taken up by plants immediately (Levy and Torrento, 1995).

Soil available phosphorus. Soil irrigated with primary treated wastewater caused an increase of available phosphorus, because Wastewater contains appreciable amount of P therefore, it brings significant increase in available phosphorus. This is most likely due to the higher P content in wastewater. Therefore, wastewater usually is a source of P and may have 5-50 mg L^{-1} phosphorus, and could be accumulate at the top soil layer (Pdscode, 1992).

Table 4. Effect of irrigation with primary treated wastewater on some chemical properties of Abo-Rawash soils.

No.	Prof. No.	Years	Depth Cm	pH	SP	EC dSm^{-1}	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{--}
							Mel^{-1}						
1	1	50	0-20	5.67	103	1.40	5.70	6.30	2.20	0.69	7.60	3.70	3.59
2			20-50	6.26	31	1.30	3.30	5.00	4.20	0.54	3.00	10.00	0.04
3			50-100	6.69	33	0.92	3.70	3.30	1.80	0.42	4.30	4.30	0.62
4	2	50	0-30	6.24	53	1.50	7.00	5.70	2.00	0.87	8.30	3.70	3.57
5			30-45	6.63	32	0.75	4.00	2.00	1.30	0.46	2.70	5.00	0.06
6			45-90	6.88	28	0.54	2.70	1.70	0.78	0.15	3.00	2.10	0.23
7	3	20	0-15	6.23	128	1.65	9.30	4.00	2.30	0.87	10.00	3.70	2.77
8			15-30	6.56	38	0.58	2.70	2.60	1.10	0.21	2.30	2.30	2.01
9			30-60	6.70	30	0.64	3.00	2.90	0.78	0.24	2.30	3.00	1.62
10			60-70	6.85	25	0.98	5.70	3.00	0.96	0.31	1.70	7.70	0.57
11			70-100	6.93	25	0.74	4.30	1.70	0.93	0.38	3.00	2.70	1.61
12	4	50	0-20	6.29	46	1.58	4.90	4.20	5.60	0.52	1.80	12.10	1.32
13			20-60	6.60	36	1.45	4.40	3.50	4.90	0.47	1.60	9.80	1.87
14			60-80	6.70	33	1.0	3.20	2.70	3.80	0.32	1.70	7.20	1.12
15			80-100	6.62	25	0.96	3.10	2.30	3.40	0.31	1.40	6.80	0.91
16	5	25	0-10	6.16	108	2.11	8.80	5.90	4.35	0.66	2.5	14.30	2.91
17			10-50	6.52	36	0.97	5.00	4.66	1.65	0.51	1.33	2.66	7.83
18			50-100	6.60	28	0.84	4.00	3.33	1.43	0.36	1.67	2.66	4.79
19	6	25	0-40	6.20	65	1.86	10.32	8.66	1.87	0.44	1.67	3.66	15.96
20			40-100	6.54	75	0.59	2.33	3.00	0.87	0.26	1.67	2.33	2.46
21	7	10	0-25	6.49	27	1.98	7.20	7.80	4.51	0.33	2.10	13.50	4.24
22			25-50	6.59	25	1.84	7.40	6.90	3.57	0.31	2.00	14.20	1.98
23			50-100	6.73	28	1.43	5.20	4.80	4.10	0.18	1.50	11.30	1.48
24	8	0	0-50	6.83	23	2.27	17.98	5.33	1.65	o.87	1.67	1.67	22.50
25			50-100	6.72	21	6.10	25.31	12.65	31.20	1.64	2.33	65.16	3.31

Table 5. Effect of irrigation with primary treated wastewater on available macro nutrients (NPK) in Abo-Rawash soils.

No.	Prof. No.	Years	Depth Cm	NO_3- N	NH_4- N	Total N	K	P
				mg kg^{-1}				
1	1	50	0-20	393.0	63.7	456.7	1190.0	138.0
2			20-50	6.6	26.2	32.8	163.0	132.6
3			50-100	0.0	20.7	20.7	102.0	40.0
4	2	50	0-30	91.0	83.2	174.2	1000.0	119.7
5			30-45	0.0	38.4	38.4	93.5	55.0
6			45-90	0.0	22.4	22.4	70.0	11.0
7	3	20	0-15	40.0	35.2	75.2	320.0	27.0
8			15-30	5.7	18.2	23.9	83.0	18.0
9			30-60	0.0	8.2	8.2	70.0	8.0
10			60-70	0.0	4.6	4.6	66.0	8.0
11			70-100	0.0	4.0	4.0	53.0	6.5
12	4	50	0-20	133.1	60.2	193.3	367.5	218.0
13			20-60	9.9	51.5	61.4	110.0	94.0
14			60-80	0.0	8.2	8.2	100.0	65.0
15			80-100	0.0	6.3	6.3	93.0	20.0
16	5	25	0-10	40.9	43.2	84.1	320.0	92.0
17			10-50	3.8	31.2	35.0	83.0	27.0
18			50-100	0.0	5.5	5.5	60.0	19.0
19	6	25	0-40	27.8	57.5	85.3	138.0	41.0
20			40-100	0.0	26.4	26.4	82.0	9.0
21	7	10	0-25	1.7	15.8	17.5	104.0	29.0
22			25-50	0.0	9.7	9.7	57.0	17.0
23			50-100	0.0	8.0	8.0	45.0	8.0
24	8	0	0-50	0.3	7.7	8.0	88.0	5.5
25			50-100	0.0	1.9	1.9	32.0	3.8

Values of availablemicronutrients in soil (Table, 6) indicate that the availability of Zn, Cu, Mn and Fe increased by irrigation with primary treatedwastewater compared to control soil; the highestaccumulation of micronutrients were found in the surface layer in soil irrigated with sewage water for fifty years and the lowest in the sub-surface layers ofcontrol soil.In case of, average DTPA-extractable Fe content in the soil irrigated with primary treated wastewater increased more thanthree to fourteen times in the primary treatedwastewater irrigated soils compered to control soil. There has been an enormous build-up in the available Fe content in the primary treated wastewater irrigated soils. Since Fe does not cause phytotoxicity in neutral to alkaline soils of this area, the build-up of available Fe is not likely to limit the use of sewage effluents for irrigation purpose.To assess the impact of duration under primary treatedwastewater irrigation, build-up of heavy metals in soils was computed separately for soil receiving irrigation for 50, 25, 20 and 10 years. In soils, which has been under wastewater irrigation for 50 years, on average 1308% build-up in Fe content was recorded and corresponding values for soil which has been receiving wastewater irrigation for 25 years was 1005%.Whereas, as a result of wastewater irrigation for 20 years, Fe increased by 434%, in soils receiving irrigation for 10 years., Fe increased by 277%.

The primary treated wastewater irrigated soils are still maintaining higher levels of DTPA-Mn than the critical limit of Mn deficiency of 2.0 mg kg^{-1} (being used currently for separating the Mn deficient in soils from the non-deficient ones).Wastewater irrigation for 50,25,20 and 10 years increased the Mn contents in soils by 829%,541%,441%and 323% compared to control soil, respectively. The highest accumulation of Mn was found in the surface layer in soil and then decreased with depth.

Zinc was affected by primary treatedwastewater irrigation, the increases in Zn concentrations were observed in soils under sewage irrigation for 50, 25, 20 and10 years. The relative increases compered to control soil reached about 267%, 185%, 252% and 52%, respectively. Application of primary treatedwastewater was highly effected on the accumulation of Zn concentration in first depth of soil profiles (0-20) then theconcentration being decrees.

Result showed that Cu concentration was higher in the primary treatedwastewater irrigated soil than in the control soil. Our results corroborate with these obtained byTarchouna *et al*,(2010).The relative increases in Cu concentration compered to control soil reached about 550%, 490%, 200% and 80%, under wastewater irrigation for 50, 25, 20 and10 years respectively. On the other hand, Saber (1996) showed that a seven-year application of wastewater had no significant effect on the concentration of Cu in the soil. Also, Adriano (2001) stated that Cu is stabilized in soil by clay minerals, organic matters and Fe, Al and Mn oxides. The vertical distribution changed over time with alternation of increase and decrease trend. This tendency agrees with McLaren *et al.* (2005) reported that Cu has certain mobility from upper horizons to lower horizons.

Table 6. Effect of irrigation with primary treatedwastewater on available micro nutrients (Fe, Cu, Mn and Zn) in Abo-Rawash soils.

Depthcm	Years	Prof. No.	Depth Cm	Fe	Cu	Mn	Zn
				mg kg^{-1}			
1	50	1	0-20	80.5	16.3	30.4	18.1
2			20-50	12.2	2.2	8.3	7.3
3			50-100	6.5	1.1	2.5	4.4
4	50	2	0-30	135.3	14.3	28.0	16.1
5			30-45	42.5	1.2	24.2	5.2
6			45-90	40.3	1.0	3.2	4.3
7	20	3	0-15	46.8	8.3	12.4	12.0
8			15-30	20.4	2.1	12.1	12.1
9			30-60	14.0	2.0	9.3	10.3
10			60-70	7.9	1.3	8.2	7.2
11			70-100	5.3	1.3	4.0	6.0
12	50	4	0-20	94.6	14.4	32.1	18.2
13			20-60	41.5	10.3	18.3	14.2
14			60-80	27.3	4.4	6.4	8.4
15			80-100	5.5	1.2	4.2	4.1
16	25	5	0-10	61.7	8.4	16.1	12.0
17			10-50	30.6	4.3	8.0	8.1
18			50-100	24.2	1.2	2.2	2.2
19	25	6	0-40	59.6	10.3	18.0	12.1
20			40-100	17.9	4.2	8.3	4.0
21	10	7	0-25	13.1	2.1	10.1	6.5
22			25-50	12.2	2.0	8.4	3.5
23			50-100	11.5	1.2	3.2	2.2
24	0	8	0-50	4.7	1.5	2.0	4.0
25			50-100	2.4	0.6	1.2	1.5

Heavy metals in soils

Application of primary treatedwastewater slight increased the Cd content(Table, 7). Similar results were observed by Brar *et al.* (2002) who reported that the concentration of Cd in soil irrigated under wastewater was increased. On the other hand, Mojiri *et al.*(2011) also reported that the irrigation with wastewater does not affect the concentration of cadmium. Overall, in our study the Cd concentration washigher in the surface layers of soil irrigated with wastewater for 50 years and levels in various soil depths were similar and no tendency was noted.

Result for Pb showed that, with the exception of the surface layerof soil profile, primary treatedwastewater used had no significant effect onPb content in other layer of the soil. Similar results were reported in Abedi-Koupai *et al.*(2006). Moreover, no significant effect was noted regarding depth. However, many authors have shown a significant decrease of Pb through the soil layers.

In the case of Nickel, soil irrigated with primary treated wastewater presented increase in Ni concentration in comparison with the control soil especially in the top layers of soil irrigated with wastewater for 50 years. All other layers showed no effect trend inNi concentration. These results were in disagreement with Vaseghi *et al.*(2005), Ni level was higher in all depths of treatedwastewater (TWW) irrigated soils comparedto both other cases (control and fresh water treatment).

Based on our study, the concentration of Mo increased in the soil by increasing the period of primary treatedwastewater utilization for irrigation this effect is more pronounced in the surface layer.Other layer did not show any significant change by wastewater irrigation.

Table 7. Effect of irrigation with primary treated wastewater on DTPA-extracted heavy metals (Pb, Ni, Mo, Cd and B) in Abo-Rawash soils.

No.	Prof. No.	Years	Depth Cm	Pb	Ni	Mo	Cd	B
				mg kg^{-1}				
1	1	50	0-20	10.81	2.22	0.23	0.16	0.54
2			20-50	0.55	0.18	0.00	0.00	0.14
3			50-100	0.36	0.02	0.00	0.00	0.10
4	2	50	0-30	6.24	3.02	0.07	0.20	0.20
5			30-45	0.27	0.65	0.00	0.06	0.11
6			45-90	0.26	0.02	0.00	0.00	0.10
7	3	20	0-15	4.97	0.65	0.04	0.01	0.09
8			15-30	0.45	0.17	0.00	0.01	0.07
9			30-60	0.27	0.05	0.00	0.00	0.07
10			60-70	0.26	0.02	0.00	0.00	0.08
11			70-100	0.15	0.02	0.00	0.00	0.05
12	4	50	0-20	8.59	2.81	0.15	0.18	1.04
13			20-60	0.67	0.31	0.00	0.01	0.12
14			60-80	0.52	0.05	0.00	0.00	0.11
15			80-100	0.44	0.02	0.00	0.00	0.10
16	5	25	0-10	3.35	1.04	0.10	0.02	0.11
17			10-50	0.40	0.51	0.00	0.01	0.09
18			50-100	0.30	0.14	0.00	0.00	0.09
19	6	25	0-40	2.90	0.83	0.04	.017	0.19
20			40-100	0.33	0.22	0.00	0.01	0.10
21	7	10	0-25	0.43	0.18	0.01	0.01	0.09
22			25-50	0.39	0.06	0.01	0.01	0.09
23			50-100	0.20	0.05	0.01	0.01	0.07
24	8	0	0-50	0.25	0.01	0.01	0.01	0.07
25			50-100	0.11	0.01	0.01	0.01	0.05

Assess the impact of duration under primary treated wastewater irrigation, build-up of B in soils was computed separately for soil receiving irrigation for 50, 25, 20, and 10 years. In soils, which has been under wastewater irrigation for 50 years, on average 316% build-up in B content was recorded and corresponding values for soil which has been receiving wastewater irrigation for 25 years was 100%.Whereas, as a result of wastewater irrigation for 20 years, B increased by 16%, and in soils receiving wastewater irrigation for 10 years. The relative increases of B reach about 33%.

Based on our study, the concentration of heavy metals (Fe, Mn, Zn,Cu, Pb, Ni, Mo, Cd, and B) was higher in top layers of primary treated wastewater irrigated soil compared to other layer of soil profiles and those not irrigated with wastewater (control soil). It has been reported that high concentration of heavy metals in wastewater leads to an increase of their content in soil (Mapanda *et al.*2005). Heavy metals are priority toxic pollutants that severely limited the beneficial use of water. Soil may adsorb and retain important amount of heavy metals from wastewater. In this study, the comparison of (Mn ,Zn, Cu ,Pb, Ni, Cd and B) with a standard level of heavy metals in soil (80,200,50,300,50,3 and 3 mg kg-1) stated by United States Environmental Protection Agency (USEPA) which reported byMasona *et al*(.2011) ,whoshowed that soils irrigated with wastewater were lower and far less in heavy metals than maximum permissible limit. The contamination of soil by some heavy metals presents a worrying situation that should be monitored to prevent further environmental and health risks. Accumulation of micronutrients and heavy metals could be caused directly by the treated wastewater composition or indirectly through increasing solubility of insoluble soil heavy metals as a result of the chelation or acidification action of the applied treated wastewater (Rusan *et al.*, 2007).

Correlation and regression analyses

Data presented in Table 8 show that the simple correlation coefficient and regression equation between some elements in soil and time factor (year). These data showed significant correlation among elements concentration and the period of primary treated wastewater application. The trends of this correlation were positive with all elements, the highest significant correlation was found between potassium,phosphorus and total nitrogen with slope equal 4.05, 1.71 and 1.23.

Table 8. Simple regression relation between some elements in soil and time factor (year).

Regression equations	R
NO_3-N = - 4.40 + 0.528 Years	0.94*
NH_4-N = 3.63 + 0.705 Years	0.99**
Total N = - 0.77 + 1.23 Years	0.99**
K = 36.1 + 4.05 Years	0.91*
P = - 6.19 + 1.71 Years	0.94*
Cu = 1.05 + 0.090 Years	0.97**
Pb = 0.104 + 0.029 Years	0.97**
Ni = - 0.0159 + 0.010 Years	0.98**
Mo = - 0.00249 + 0.0003 Years	0.98**
Fe = 5.23 + 0.834 Years	0.99**
Cd = - 0.00416 + 0.0006 Years	0.92*
B = 0.0685 + 0.0028 Years	0.93*

Data presented in Table 9 show that the simple correlation coefficient and regression equation between pH values and some elements concentration in soil.These data showed significant correlation among pH and elements concentration. The trends of this correlation were negatively with all elements,the highest significant correlation was found between pH and Cd, B and Ni with slope equal 2.95, 0.699 and 0.232. Multiply correlation coefficient (R) and multiply regression equation between some elements concentration (y) and period of primary treated wastewater application (x1), depth of profile cm (x2) are summarized in Table 10.The best parameter models were for potassium which was positively correlated with period of wastewater application and negative correlated with depth of profile, with Factor of variables x1 = 6.36 and x2 = - 5.26, with significant multiply correlation (R = 0.65* *), respectively.

Table 9. Simple regressionrelation between pH and some elements in soil.

Regression equations	R
pH = 6.67 - 0.0809 Pbmg kg^{-1}	- 0.81**
pH = 6.65 - 0.232 Ni mg kg^{-1}	-0.71**
pH = 6.61 - 2.95 Cd mg kg^{-1}	-0.61**
pH = 6.64 - 0.699 B mg kg^{-1}	-0.51**
pH = 6.85 - 0.0405 Zn mg kg^{-1}	-0.71**
pH = 6.77 - 0.0221 Mnmg kg^{-1}	-0.71**
pH = 6.74 - 0.0475 Cu mg kg^{-1}	-0.80**
pH = 6.72 - 0.00583 Fe mg kg^{-1}	-0.67**

In short, the multiply correlation coefficient and the multiply regression equation of total nitrogen the best multiply regression equation was found which was positively correlated with period of wastewater application and negative correlated with depth of profile, with Factor of variables x1 = 2.22 and x2 = - 1.85, with significant multiply correlation (R = 0.67**). Consequently, in case of phosphorus concentration the best multiply regression equation was found which was positively correlated with period of wastewater application and negative correlated with depth of profile, with Factor of variables x1 = 1.95 and x2 = - 1.03, with significant correlation (R = 0.82**)

Table 10. Multiple regression relation between some elements(mg kg^{-1}) and both of time (year) and depth of sample in soil profile (cm).

Multiple regression equations	R
NO_3-N = 40.9 + 1.55 Year - 1.31 Depth cm	0.56*
NH_4-N = 29.9 + 0.664 Year - 0.540 Depth cm	0.85**
Total N = 70.9 + 2.22 Year - 1.85 Depth cm	0.67**
K = 235 + 6.36 Year - 5.26 Depth cm	0.65**
P = 34.8 + 1.95 Year - 1.03 Depth cm	0.82**
Pb = 2.74 + 0.0582 Year - 0.0629 Depth cm	0.70**
Ni = 0.732 + 0.0205 Year - 0.0187 Depth cm	0.73**
Mo = 0.0438 + 0.00104 Year - 0.00114 Depth cm	0.64**
Fe = 37.0 + 0.890 Year - 0.709 Depth cm	0.77**
Cd = 0.0305 + 0.00148 Year - 0.00107 Depth cm	0.67**
B = 0.150 + 0.00454 Year - 0.00297 Depth cm	0.56*
Zn =10.3 + 0.133 Year – o.129 cm	0.82**
Cu = 6.9 + 0.109 Year – 0.111 cm	0.76**
Mn = 13.8 + 0.242 Year – 0.229cm	0.84**

According to the multiple regression equations in Table 10, time in years was calculated to prediction when soil will be reach to toxic level for some elements in the soil as result of applying this type of wastewater for irrigation was reported in Table 11.

Table 11. Time in years which is needed to reach to toxic concentrations of some elements in the soil.

Element	Toxic con. (mg kg-1)	Years	
		In surface layer (20 cm)	In whole profile (100cm)
Pb	300	5129	5216
Ni	50	2422	2495
Cd	3	2021	2079
B	3	641	693
Cu	50	423	505
Mn	80	292	368
Zn	200	1446	1523

It was clear that soil take very long time for reach to toxic concentration of Pb, Ni, Cd, B, Cu, Mn and Zn under application of primary treated wastewater for irrigated. Simply, according to soil chemistry or plant nutrition it could be consider that this primary treated wastewater is safely used for irrigation for long time.

Assessment of some nutrient and heavy metals enrichment factor (EF) in Soils.

Enrichment factor is an indication of the anthropogenic impact on soil also; enrichment factor can give an insight into differentiating an anthropogenic source from a natural origin (Chopra and Pathak.2013)Data presented in Table 12 show that theenrichment factor of some nutrient in the soil under sewage irrigation for 50, 25, 20 and10 years.

Table 12. Enrichment factor of some nutrient in the soil under investigated.

Prof. No.	Years	Enrichment Factor (EF)						
		TN	P	K	Fe	Mn	Zn	Cu
1	50	34.7	22.5	8.1	9.5	8.6	3.7	6.5
2	50	15.9	13.5	13.1	20.8	11.6	3.1	5.5
3	20	4.7	2.9	1.9	5.4	5.7	3.5	3.0
4	50	13.7	21.6	2.8	12.1	9.5	4.1	7.6
5	25	8.5	10.0	2.6	11.1	5.5	2.7	4.6
6	25	11.2	5.4	1.8	11.1	8.2	2.9	7.2
7	10	2.4	3.9	1.1	3.5	4.5	1.4	1.8

The enrichment factor of the total nitrogen varied from 2.4 to 34.7 represent moderate enrichment to very high enrichment. The high valuewas associated with soil receiving primary treatedwastewater irrigation for 50 years and the lowest value was the soil irrigated with wastewater for 10 years.Similar results were observed for phosphorus the enrichment factor varied from 2.9 to 22.5 represent moderate enrichment to very high enrichment. The high value for soil irrigated with primary treated wastewater for 50 years and lowest value for 20 years irrigated soil. Based on our study, the enrichment factor of potassium increased in the soil by increasing the period of sewage water utilization for irrigation this effect is more pronounced in the soil receiving wastewater for 50 years which have enrichment factor reach about 13.1 represent significant enrichment. But soil irrigated with wastewater for 10 years result enrichment factor about 1.1 represent depletion to minimal.The enrichment factor of Fe varied from 3.5 to 20.8 represent moderate enrichment to significant enrichment. The high value was associated with soil receiving primary treated wastewater irrigation for 50 years and the lowest value was the soil irrigated with wastewater for 10 years. Sewage irrigation for 50, 25, 20 and 10 years increased the enrichment factor ofMnrecorded value of 9.9, 6.8, 5.7 and 4.5, respectively which represent moderate enrichment to significant enrichment. Zinc was affected by sewage irrigation the enrichment factor of Zn varied from 1.4 to 4.1 represent depletion to minimal enrichment to moderate enrichment. As for Cu the enrichment factor varied from 1.8 to 7.6 represent depletion to minimal enrichment to significant enrichment. There are significant differences in enrichment factor values among the elements. When enrichment value is high (>1) it indicates higher availability and distribution of metals in soil irrigated with contaminated water and thereby increasing the average heavy metal concentration in major crops, vegetables and weeds in wastewater irrigated area with respect to their reference values (Kisku *et al*., 2000).

For each of the other examined heavy metals (Table, 13),the enrichment factor of Pbvaried from 1.9 to 21.7 represent depletion to minimal enrichment to very high enrichment. The high value was associated with soil receiving primary treatedwastewater irrigation for 50 years and the lowest value was the soil irrigated with wastewater for 10 years. Similar, the enrichment factor of Ni varied from 10.0 to 103.0 represent significant enrichmentto extremely high enrichment. Moreover, the enrichment factor of Mo varied from 1.0 to 8.0 represent depletion to minimal enrichment to significant enrichment. As for Cd the enrichment factor was varied from 1.0 to 9.0 represent depletion to minimal enrichment to significant enrichment. Finely, the enrichment factor of B varied from 1.3 to 5.7 represent depletion to minimal enrichment to significant enrichment.The enrichment factor of the heavy metals in soil were in the sequence of Ni >Pb> Cd > Mo > B.

Table 13. Enrichment factor of some heavy metals in the soil under investigated.

Prof. No.	Years	Enrichment Factor (EF)				
		Pb	Ni	Mo	Cd	B
1	50	21.7	81.0	8.0	5.0	4.3
2	50	12.5	103.0	2.0	9.0	2.3
3	20	6.8	18.0	1.0	1.0	1.2
4	50	14.2	79.0	4.0	5.0	5.7
5	25	7.5	56.0	3.0	1.0	1.5
6	25	8.9	52.0	2.0	2.0	2.3
7	10	1.9	10.0	1.0	1.0	1.3

CONCLUSION

This study contributes to the evaluation of primary treated wastewater effects on some chemical properties of soil; we found some variations in the soil properties as a result of primary treatedwastewater application.We have detected a decrease in pH and EC for soil irrigated with primary treatedwastewater comparison with soil not irrigated with wastewater. Also, soil irrigated with primary treatedwastewater caused an increase of available nitrogen, potassium and phosphorus. Our results indicated that the availability of Zn, Cu, Mn and Fe were increased by irrigation with primary treatedwastewater compared to control soil; the highestaccumulation of micronutrients was found in the surface layer in soil irrigated with sewage water for fifty years and the lowest in the sub-surface layers of control soil. Application of primary treated wastewater slight increased the heavy metals content but still within the permissible limits in sewage irrigated soils. There is a great respite that accumulation of heavy metalshas not posed any threat even after such long-term use of thiswastewater. The results of this study showed that wastewater reuse in irrigation must be conditioned by some management measures such as soil texture, plant selection and the choice of irrigation methods.

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بعض الخواص الكيميائية للاراضى وتأثرها بالاستخدام المستمر لمياة الصرف الصحى المعالج اولية

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اجريت دراسة حقلية بمزرعة ابو رواش بمحافظة الجيزة وذلك لدراسة تأثير الرى بمياة الصرف الصحى ذات المعالجة الاولية على بعض الخواص الكيميائية للاراضى تحت الدراسة وقد تم اختيار ثمانى قطاعات ارضية تمثل اراضى تم ريها لفترات زمنية مختلفة بمياة الصرف وهذة الفترات هى صفر,10, 20, 25 و50 عام . وقد اوضحت التحاليل المختلفة التى تم اجرائها ان محتتوى مياة الرى من الاملاح الذائبة والعناصر الكبرى والصغرى بالاضافة الى العناصر الثقيلة كانت فى الحدود المسموح بها للاستخدام فى الرى.وقد اوضحت النتائج ايضا ان المحتوى كان مرتفع لكل من النتروجين والفوسفور والبوتاسيوم فى الاراضى التى تم ريها بمياة الصرف الصحى بالمقارنة مع تلك التى لم تتعرض للرى بمياة الصرف الصحى. وقد اظهرت الدراسة ان استمرار الرى بمياة الصرف الصحى ذات المعالجة الاولية ادت الى انخفاض رقم الحموضة والملوحة فى التربة كما ادت ايضا الى زيادة تيسر الحديد والمنجنيز والزنك والنحاس والعناصر الثقيلة مثل الرصاص والنيكل والمولبدنيم والكادميوم والبورن بالمقارنة بالاراضى التى لم تروى بمياة الصرف الصحى وكانت هذة الزيادة ملحوظة بدرجة كبيرة فى الطبقة السطحية من القطاعات تحت الدراسة والتى تعرضت للرى لمدة 50 عام. وقدكان عامل الاثراء للعناصر الثقيلة مرتفعا للاراضى المعرضة للرى بمياة الصرف الصحى وقد اتخذ الترتيب التالى النيكل > الرصاص > الكادميوم > المولبدنيوم > البورون.