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Spatial and Temporal Soil Variability under the Safe Use of Low Quality Water for Irrigation at Burg El-arab Area, Egypt

H.M. Ramadan and M.E.El-Fayoumy

Soils, Water and Environment Reserch Institute,Agric. Res. Center, Giza, Egypt.

A COMPARATIVE field study was undertaken during March, 1999 to evaluate the safe use of low quality water for irrigation of some soils calcareous in nature at Sewage Waste Station Farm- New Burg El-Arab city, North West Coast, Egypt. The irrigation water resources were treated sewage waste water (Sw) for three different periods; (two years, Sw2; three years, Sw3 and six years, Sw6), industrial waste water (mw), mixture of Nile water and drainage water (Mw from Bahige canal) and rainfed (R) as another source of water for comparison.

The results indicated that application of different wastewaters was affected the physical properties, where it was tended to increase the water stable aggregates and structure coefficient as follows for the treatments of Sw6> Sw3 > Sw2 > Inw> R > Mw. Also, the bulk density was decreased with increasing the period of application, as shown for the different sources of irrigation water: Sw6< Sw3< Sw2< Inw< R<Mw.The hydraulic conductivity increased with increasing the period of irrigation wastewater as follows: Sw6 > Sw3 > Inw> Sw2 > R >Mw. The unconfined compressive strength value of industrial waste was 0.5 ton/f^2 and represented medium class, as well as, its values were taken a regular trend decreased with increasing the period of wastewater irrigation as follows: Inw < Sw6 < Sw3< Sw2< R <Mw. Soil moisture characteristics curves showed that irrigation with wastewater caused an increase of soil moisture content. It's values increased as follows: Sw6>Sw3> Sw2> Inw> Mw> R.

The results showed that application of the different wastewater was associated with some changes for soil chemical properties. The trend of soil pH followed the sequence Sw6 <Inw< Sw3 <Sw2 <R < Mw. The electrical conductivity values had the sequence of, Mw > Inw>Sw6 > Sw3> Sw2 > R. The values of DTPA- Pb, Zn and Fe increased as follows: Inw >Sw6> Sw3> Sw2 > Mw> R>.While, the values of Ni, Zn and Mn had the following trend, Sw6 > Sw3> Sw2 > Inw > Mw> R.

The geostatistical analysis showed that three semi-variogram models fitted the individual soil properties. The fitted models were exponential for DTPA- Fe and Cl^-, spherical for DTPA- Zn , Mn & Ni and Na^+, while DTPA-Cu, Pb , EC and SAR were Gaussian. Semi-variogram model parameters showed that EC and heavy metals have the highest nugget variance, which indicated their strong spatial dependence and high inherited variability. The kriging map showed that the spatial and temporal variability of heavy metals in the studied area.

Keywords: Sewage waste water, Industrial waste water, Semi-variogram, Kriging and Spatial and Temporal variability.

The scarcity of freshwater for agriculture in the arid zone area is considered the most limiting factor in the coming twenty-one century for food production. So, many countries, including Egypt, started to look to wastewater reuse for irrigation and crop production in order to cover the shortage of freshwater and meet their demands for more food production.

The increased amounts of municipal and industrial wastewaters and its disposal are considered one of the most important problem around the world. The attempts to reuse those wastes as a source of irrigation and plant nutrients, particularly in the semi-arid and arid regions, have been reported (Day *et al.,* 1981, Cambell *et al.,* 1983 and Bieloria *et al.* 1984).

Rabie *et al.* (1996 a) studied the contents of Biogenic (Fe, Mn, Zn, and Cu) and non-Biogenic (Pb and Cd) heavy metals in El-Saff soils as related to different pollution sources (different industrial activities- sewage waste) as well as a virgin non-irrigated soils for comparison. They found that the highest content of the trace elements (Fe, Mn, Zn, Cu, Pb and Cd) in all sites was found in the surface layers of soils irrigated with polluted sources. The average content of total Fe, Mn, Zn, Cu, Pb and Cd in the surface layer of the soils irrigated with industrial wastes are 15.65 %, 2340 ppm, 399 ppm, 167 ppm, 129 ppm and 1.9 ppm, respectively. In soils, irrigated with sewage waste, the average content of these elements was 4.03 %, 514 ppm, 585 ppm, 252 ppm, 189 ppm and 3.3 ppm, respectively. The virgin non-irrigated soils on the other hand, contains 1.42%, 160 ppm, 28 ppm, 69 ppm, 65 ppm and 0.6 ppm of Fe, Mn, Cu, Pb and Cd, respectively.

Rabie *et al.* (1996 b) studied the distribution of different heavy metals in the different particle size fractions of soils irrigated with different industrial sewage wastes. They found that the highest values were found in clay fraction, while the lowest ones were found in sand fraction. In addition, all fractions of soils irrigated with industrial wastes have the highest amounts of Fe and Mn, while fractions of soils irrigated with sewage wastes have the highest amounts of Zn, Cu, Pb and Cd. Data showed that the enrichment of heavy metals in the clay fraction is about 33, 24, 14, 13, 12 and 10 times as compared to the sand fraction for Mn, Cu, Fe, Cd, Zn, and Pb, respectively. The degree of enrichment, on the other hand, varies between 1-1.5 times for the various metals in the silt fraction compared to sand fraction.

Elsokkary and Sharaf (1996) studied two cultivated regions representing alluvial and lacustrine soils. The source of water for irrigation in alluvial soils is a mixture of agricultural drainage and domestic effluents and that of lacustrine is a mixture of agricultural drainage, domestic and industrial effluents. The soils were enriched by Cd and to some extent by Zn. The amounts of DTPA-Zn and-Cd represented about 0.5 and 13% of the total in alluvial soil and about 0.8 and 13% of the total in soil of lactustrine soils, respectively.

Abdel-Sabour *et al.* (1996) investigated five heavy metals content namely Fe, Zn, Cu, Co and Pb in Cairo sewage effluent being used in irrigation of sandy soil of El-Gabel El-Asfar farm. It was noticed that total Zn in sewage sludge and sewage effluent were higher than the permissible doses agreed by the USA-EPA. Copper concentration was at the upper critical permissible dose. However, Pb was less than those reported by USA-EPA. They reported that large amounts of Fe, Zn, Cu and Pb accumulated over 52 years of irrigation with Cairo sewage effluent in the order: Fe >Zn >Pb >Cu >Co. El-Gamal (1980) reported that the average concentration of heavy metals in raw and final effluents from El-Gabal Asfer, were 0.01,0.04,0.63,0.15, 0.10 and 0.15 ppm for Cd, Cu, Fe, Mn, Pb and Zn, respectively.

El-Khames (1982) studied the effect of Alexandria sewage application on the physical properties of sand, loam and loamy sand soils. He found that continuous and intermittent application of the raw and treated sewage did not significantly change the particle size distribution, real density, porosity and saturation percent (the time of experiment was one month). Whereas, infiltration rate and hydraulic conductivity were affected in sandy soil only, while in loamy and loamy sand soil they did not significantly change. In sandy soil, the highest values of the infiltration rate were obtained by the use of treated sewage.

Gomma (1989) concluded that the relative reduction in infiltration and cumulative infiltration, which occur following irrigation with different wastewater effluents, is greater in fine-textured soil (Abis). The differences in the response of these soils to wastewater effluents probably results from their different physicochemical characteristics.

Bahri (1988) showed that the application of treated wastewaters at the La Soukra and Oued Souhil experimental stations, Tunisia where the soils are alluvial and sandy clayey to sandy, has not adversely affected the physical or bacterial quality of the soils. However, the chemical quality of the soils varied considerably, with an increase in electrical conductivity and a transformation of the geochemical characteristics of the soil solution from bicarbonate-calcium to chloride-sulfate-sodium. Also, trace elements concentrated in the surface layer of soil, partically zinc, lead, and copper, but did not increase to phytotoxic levels in the short term of the study period. He noticed that irrigation with treated wastewaters was not found to have an adverse effect on the chemical and bacteriological quality of shallow groundwater.

Abdel Sabour *et al.* (1988) showed a great variability especially for the Fe and Zn which could be attributed to the spatial (vertical and horizontal) variability in the soil profile due to the following factors; 1- The non tillage system in El-Gabal El-Asfer farm. 2-The surface effluent irrigation which may add suspended materials to soil surface which are enriched in heavy metals content. These variations are measured by the standard deviation and that would suggest the importance of increasing the sample size (number) to avoid the erratic results of the non-representative samples.

The objectives of the present work were to study the spatial and temporal soil variability under irrigation with the different treated wastewater and mixture of Nile water and agriculture drainage water on some soil physical and chemical properties.

Material and Methods

(a) *Field work*

A comparative study was undertaken to evaluate the safe use of the low quality water for irrigation at Sewage Waste Station Farm, New Burg El-Arab City, North West Coast, Egypt. The sources of irrigation water were sewage waste, industrial waste, mixture of Nile water with agriculture drainage water (Bahige canal) and rain fed. Soil samples were collected in March, 1999 from the surface (0-30 cm) and subsurface layers (30-60 cm) from different soil sites that were irrigated with treated sewage water for three different periods (2,3 and 6 years), industrial waste water (1 year), mixed water and rainfed. Also, Water samples were collected from the treated sewage waste basin, treated industrial waste basin, mixed water (Bahige irrigation canal) and rain water (Table 1). The studied soil is characterized by texture class of sandy loam (sand 59.5 %, silt 21.35% and clay 19.15%) and calcareous in nature (average total $CaCO_3$ 32.4%).

TABLE 1. Different sources of irrigation, total area feddan, number of soil observations and major cultivated crops.

Source of water	Abbreviation	Total area (feddan)	Number of soil observations	Major crops
Treated sewage waste (2 year)	Sw2	150	15	Grape and Mulberry
Treated sewage waste (3 year)	Sw3	40	5	Grape and Mulberry
Treated sewage waste (6 year)	Sw6	100	10	*Melia Azerachta* (Neem)
Treated industrial waste (1 year)	Inw	15	10	Uncultivated
Mixed water (Bahige canal)	Mw	10	10	wheat , tomato and egg plant
Rainfed	R	10	5	Wheat and barely
Total		315	55	

(b) *Laboratory analysis*

Water analysis

The average values of the major characteristics for the treated waste and mixed waters are given in Table 2. The effluent of wastewater contains moderate (treated waste) to high salinity (mixed water), but it hasn't alkalization risk, as well as, the trace element concentrations are below toxicity thresholds. Chemical analysis of the water samples was done according to Page *et al* (1982).

TABLE 2. Average values of the major characteristics of treated waste and mixed waters used for irrigation in the studied farm.

Treatments	pH	EC	Pb	Ni	Fe	Zn	Mn	Cu
		dS/m	(ppm)					
Sewage waste water	7.22	1.42	0.08	0.16	0.50	0.25	0.20	0.03
Industrial waste water	6.80	1.80	0.19	0.16	0.35	0.70	0.14	0.08
Mixed water	8.40	2.97	0.02	0.04	0.24	0.02	0.00	0.01

Soil physical analysis

Particle size distribution was carried Out by the Bouyoucos hydrometer method (Black, 1965).

Water stable aggregates wet sieving was carried out using the wet sieving technique described by Yoder (1936) and moified by Ibrahim (1964). The wet sieving stability (WSS) was calculated using the equation:

$$WSS=(m/M)\ 100$$

where; m= the weight of water stable aggregates fraction in g and M= weight of the soil sample used in g.

Structure coefficient values (SC) were calculated as suggested by El-Shafei and Ragab

(1975).

$$SC = \frac{\%\ \text{aggregates} > 0.25\ \text{mm diameter}}{\%\ \text{aggregates} < 0.25\ \text{mm diameter}}$$

Bulk density (Db), total soil porosity (E) and hydraulic conductivity (Kh). The undisturbed soil samples were taken using soil cores to determine bulk density and hydraulic conductivity by using constant head method (Klute, 1965). Total soil porosity was calculated as a percentage by using the equation of $E = (1-Db/Dr) \times 100$.

Where; Db : Bulk density , Dr : Real density.

Intrinsic permeability (Ki). It refers to the permeability of soil to water. It is calculated according to the given equation: $Ki = Kb. (*\acute{\eta} /dw.g)$, in which Ki =

intrinsic permeability (cm^2), Kh= hydraulic conductivity (cm/sec), $\acute{\eta}$ = viscosity of water at the recorded temperature (poises; 0.01 at 20 °C) dw = Density of water (1 gm/cm^3), g= Acceleration of gravity (980 cm/sec^2). The ratio ($\acute{\eta}$/dw.g) equal to: 1.02×10^{-5}, i.e Ki =Kh.1.02×10^{-5} (Black, 1965).

Unconfined compressive strength (UCS). The pocket penetrometer was used to measure soil resistance to deformation forces, (Black, 1965). The penetrometer was pushed steady into the soil. The maximum deformation of the spring, as the piston needle is pushed into soil has been correlated with unconfined compressive strength of Toni Ft^2. The values of unconfined compressive strength of soil are calibrated directly on a scale on the piston barrel. It could be expressed in terms of consistency according to Black 1965 as follows: Very soft: < 0.25, Soft: 0.25-0.50, Medium: 0.5-1.00, Stiff: 1.00-2.00, Very stiff: 2.00-4.00 and Hard: > 4.00.

Soil moisture characteristic curves

The moisture tension characteristic relationship for the soil treated with different sources of irrigation water were determined as cited by (Richards, 1954).

Soil chemical analysis

Chemical analysis was done on soil samples sieved through a 2 mm sieve. Soil pH was determined using a 1:2.5 soil water suspension. Electrical conductivity and soluble cations and anions of soil saturation paste extract were determined (Richards,1954). Available trace elements were estimated according to the method of Lindsay and Norvell (1978) using DTPA solution. Measurements of trace element were carried out using Atomic Absorption Spectrophotometer (AAS). $CaCO_3$ content was determined volumetrically using Collin's calcimeters as described in Black (1965).

Geostatistical analysis

The semi-varigram (γ) is the heartbeat of geostatistical. It is the basis for modeling the data set and for drawing contour maps. This function relates the similarity or difference, expressed as the semi-variance, between values at different places to their separation in both distance and direction (Warrick *et al.*, 1986). The semi-variance is defined as follows:

$$\gamma (h) = 1/2 \ \mathrm{Var}\, [Z (x) - Z (x+h)]$$

where; Z(x) and Z(x+h) are the values of a random function representing the soil property of interest, Z at places x and x+h separated by vector h known as the lag and Var is the variance.

The obtained semi-variance values for each lag were fitted to one of the semivariogram functions using the GSPLUS geostatistical analysis software, Gamma Design (1991). The semi-varigram model with its parameters is shown in Fig. 1, as an example of how these models and their parameters are illustrated on graphs.

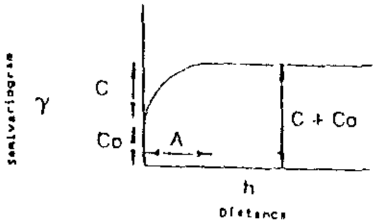

Fig.1. Typical variogram model and its parameters (adopted from Warrick *et al.*, 1986).

γ : the semi-varigram
Co +C : the sill variance
h : the lag distance
Co : the nugget variance
A : the lag distance

The nugget (Co) is the semi-variance values due to short scale or inherited variability; the range (A) is the distance at which the semi-variance reaches its maximum, after which there is no spatial dependence occur among the samples, and within it interpolation is worth while; and (Co+C) is the plateau (constant value) that the semivarigram reaches (Issaks and Srivastava, 1989).

Kriging is a method of interpolation using the weighted local averaging. It is optimal in a sense that the weights are chosen to give unbiased estimates, while keeping the estimation variance at minimum (Webster, 1985). Kriging maps and three-dimensional (3D) were calculated and drown using software, Surfer (1994).

Results and Discussion

Soil physical properties

Water stable aggregates (WSA) and structure coefficient (SC)

The water stable aggregates increased with increasing the period of application for the different sources of irrigation water. Sewage wastewater application caused an increase in the coarse aggregates as shown in Table 3. The highest increase in the coarse aggregates was found after the period 6 years, where the > 0.25 mm aggregates were 45.86 % and 34.80 % in the surface and subsurface layers, respectively. The reverse is true for the mixed water, which was enhanced the particles dispersion, where the fine aggregates diameter of < 0.25 mm was 90.86 % Vs 9.14 % for the coarse aggregates (> 0.25 mm). This trend is due to the relatively high Na-salts, which induced an increase in ESP, which was considered the most sensitive parameter affecting soil structure. In general, the wastewater application increased the values of water stable aggregates and SC as shown, in the following trend: Sw6 >> Sw3 > Sw2 >= Inw > R > Mw. On possible benefit of irrigation wastewater to soil was the establishment of more stable soil structure, and in turn more improvement for soil physical characteristics.

TABLE 3. Water-stable aggregates and structure coefficient of soil affected with the different water resources.

Treatments	Depth (cm)	Water-Stable Aggregates (WSA) %						SC
		>2.0 mm	2.0-1.19 mm	1.19-0.50 mm	0.50-0.25 mm	> 0.25 mm	< 0.25 mm	
Sw2	0-30	0.48	4.74	8.20	13.79	27.21	72.79	0.37
	30-60	0.16	1.36	2.83	6.19	10.54	89.46	0.12
Sw3	0-30	3.16	3.26	6.32	18.76	31.50	68.50	0.46
	30-60	1.98	2.75	2.95	14.96	22.64	77.36	0.29
Sw6	0-30	4.38	5.36	11.75	24.37	45.86	54.14	1.18
	30-60	2.10	5.67	9.04	17.99	34.80	62.20	0.50
Inw	0-30	1.98	2.75	2.95	14.96	22.64	77.36	0.29
	30-60	4.39	1.78	7.90	14.53	28.60	71.40	0.40
Mw	0-30	0.10	1.55	1.55	4.29	9.14	90.86	0.08
	30-60	1.39	2.52	3.08	7.86	14.85	85.15	0.17
R	0-30	2.17	2.99	2.89	6.65	14.70	85.30	0.17
	30-60	0.97	1.89	3.23	7.68	13.77	86.23	0.16

Bulk density (Db) and porosity (E)

Bulk density had different trends (Table 4), using the wastewater was tended to reduce the values of soil bulk density. Bulk density values were reduced to 1.3,1.2,1.0 and 1.35 g/cm^3 under the applications of the Sw2, Sw3 ,Sw6 and

Inw, respectively, at the surface as compared with 1.55 g/cm^3 for the rainfed. Also, in the subsurface layer the values were 1.5, 1.35, 1.2 and 1.5 g/cm^3 for Sw of the period Sw2, Sw3, Sw6 and Inw, respectively, as compared with 1.62 g/cm^3 for the rainfed. The decrease of bulk density was due to the increase of organic residue content of Sw, (Gomma, 1989). The bulk density value for soil irrigated with Mw was increased to 1.45 and 1.58 g/cm^3 at the surface and subsurface layers, respectively. Actually, reuse of drainage water increased of Na-salts addition.

TABLE 4. Man physical characteristics of soils affected with the different water resources.

Treatments	Depth , (cm)	Db , (g/cm3)	Kh , (cm/hr.)	UCS, (ton/ft^2)	E (%)	Ki (cm^2)
Sw2	0-30	1.30	1.34	3.8	50	3.79 x 10^{-9}
	30-60	1.50	1.29	3.4	42	3.65 x 10^{-9}
Sw3	0-30	1.20	2.20	3.3	54	6.23 x 10^{-9}
	30-60	1.35	1.35	3.5	48	3.82 x 10^{-9}
Sw6	0-30	1.00	3.10	1.5	61	8.78 x 10^{-9}
	30-60	1.20	1.42	3.5	54	4.02 x 10^{-9}
Inw	0-30	1.35	1.89	0.9	48	5.35 x 10^{-9}
	30-60	1.50	1.72	2.0	49	4.87 x 10^{-9}
Mw	0-30	1.45	0.90	4.1	44	2.55 x 10^{-9}
	30-60	1.58	1.10	4.5	39	3.11 x 10^{-9}
R	0-30	1.55	1.20	4.2	40	3.40 x 10^{-9}
	30-60	1.62	1.25	4.5	37	3.54 x 10^{-9}

In general, the trend of bulk density values decreased as follows; Sw6 < Sw3 < Sw2 <= Inw < R <Mw. The change of total porosity follows and depends on the changes in Soil bulk density as mentioned before.

Hydraulic conductivity (Kh) and Intrinsic permeability (Ki)

With respect to hydraulic conductivity, data showed that it was widely affected by wastewater (Table 4). Hydraulic conductivity values were increased to 3.1,2.2,1.34 and 1.89 cm/hr for Sw2, Sw3, Sw6 and Inw, respectively at the surface layer when compared with 1.2 cm/hr for the rainfed. Furthermore, its values in the subsurface layer were 1.42,1.35,1.29, and 1.72 cm/hr for the above water treatments as compared with 1.25 cm/hr for the rainfed. Higher Kh of soil, which was affected by wastewater, could be attributed to change in soil physical properties resulting from organic residue decomposition (Gomma, 1989). Of course, values of the intrinsic permeability had the same and expected trends as that of hydraulic conductivity.

Unconfined compressive strength

The results of unconfined compressive strength revealed a regular trend between the period of the irrigation with sewage wastewater and industrial wastewater (Table 4). The unconfined compressive strength values were 1.5,3.3,3.8 ton /ft^2 at the periods of Sw application for 6,3,2 years at the surface layer, respectively. These values represent very stiff class. On the other hand, UCS value of Inw was 0.5 ton /ft^2 and represented medium class for the surface layer.

Soil moisture characteristics curve

Soil moisture content at different tensions from 0.1 to 15 bar for soils treated with different sources of irrigation water are given in Table 5. Data obtained indicated that the use Sw6 caused the greater values of the water content at any particular tension in both surface and subsurface layers. The soil moisture content increased with increasing the period of Sw application. Soil moisture values for the different period, of Sw2, Sw3, Sw6 were higher than the Inw. This is mainly due to the organic residue in sewage and industrial wastes fill the pores between soil particles and increased the small pores which would hold more moisture (Gomma, 1989). The data revealed that the Sw and Inw increased the available water, (Table 5) as the following trend: Sw6> Sw3 > Sw2 > Inw >Mw>R.

TABLE 5. Soil moisture percentage (on weight basis) at the different tensions for the studied soils treated with the different sources of irrigation water.

Treatment	Depth (cm)	Tension (bar)							AW*
		0.1	0.3	0.5	1.0	3.0	5.0	15	
Sw2	0-30	57.97	38.17	26.31	11.66	9.25	6.87	3.08	34.09
	30-60	61.45	36.39	28.87	19.80	8.66	7.57	3.52	32.87
Sw3	0-30	41.35	41.16	36.22	17.35	11.83	9.58	4.69	36.47
	30-60	68.24	43.95	37.35	20.17	11.85	6.86	3.97	39.98
Sw6	0-30	68.99	45.54	40.15	25.83	14.86	12.18	5.63	39.91
	30-60	73.42	46.62	40.43	24.18	16.82	8.36	4.80	41.82
Inw	0-30	55.28	33.95	25.69	25.07	11.64	6.84	3.26	30.69
	30-60	63.03	42.99	28.67	25.24	14.86	11.34	5.36	37.63
Mw	0-30	43.25	24.56	15.63	19.89	7.22	5.11	2.65	21.91
	30-60	41.65	16.35	14.02	12.53	4.10	3.58	2.40	13.95
R	0-30	41.28	23.25	15.60	12.10	6.75	4.63	2.53	20.72
	30-60	40.36	24.80	14.30	10.20	4.78	3.20	2.40	22.40

*AW: Available water.

Chemical properties

The chemical characteristics of the studied soils are shown in Table 6. Wastewaters application was tended to decrease soil pH, especially in the surface layer, may have been caused by intensing nitrification of NH4-N and formation of organic acids and hydrogen ions. On the other hand, Mw caused an increase in soil pH up to 8.58, where the enrichnient of the soil by Na ions is due to the use of this water quality. General trend of soil pH followed the sequence of Sw6 <Inw < Sw3 <Sw2< R <Mw, (Table 6).

Electric conductivity (EC, dS/m) values were slightly increased as a result of using the wastewater. Whereas, usage of the mixed water was increased the EC value due to the high salts input of irrigation. Generally, the trend of EC values followed the sequence of Mw >>Inw > Sw6 > Sw3 > Sw2 > R, Table 6.

Cations distribution follows the decreasing order of sodium > calcium > magnesium > potassium, while anions can be arranged in the order of sulfate> chloride > bicarbonate.

TABLE 6. Chemical analysis of soil affected with the different water treatments.

Treatments	Depth (cm)	pH	EC (dS/m)	Cations (meq/l)				Anions (meq/l)			SAR
				Ca^{++}	Mg^{++}	Na^+	K^+	HCO_3^-	Cl^-	SO_4^{--}	
Sw2	0-30	7.98	3.07	12.30	3.84	17.93	1.79	4.48	16.14	15.28	6.31
	30-60	8.37	2.90	11.61	3.63	16.23	1.62	4.06	14.60	13.84	5.88
Sw3	0-30	7.90	3.59	14.35	4.48	15.37	1.54	3.48	13.84	13.38	5.01
	30-60	8.27	3.25	12.98	4.06	14.52	1.45	3.63	13.07	12.30	4.97
Sw6	0-30	7.47	3.70	15.03	4.70	18.79	1.88	4.70	16.91	15.99	5.98
	30-60	7.90	3.30	13.20	4.13	16.50	1.65	4.13	14.85	14.02	5.61
Inw	0-30	7.82	5.43	21.74	6.79	27.17	2.72	6.79	24.46	23.05	7.19
	30-60	8.12	3.93	15.71	4.91	19.64	1.96	17.68	4.91	22.59	6.12
Mw	0-30	8.58	8.24	17.95	10.30	56.18	4.15	10.30	37.07	35.03	14.95
	30-60	8.23	4.78	15.03	5.98	27.91	2.39	5.98	21.52	20.30	8.61
R	0-30	8.44	2.75	11.00	3.44	13.75	1.38	12.38	3.44	8.49	5.12
	30-60	8.41	2.39	9.57	2.99	11.96	1.20	10.76	2.99	10.15	4.79

Data illustrated in Table7 revealed that the portions of Mn, Cu and Ni extracted with DTPA were higher than the critical levels. The DTPA extracted Pb and Zn were at much higher levels than the environmentally acceptable. The DTPA- Fe was higher than the critical levels in the cases of 8w6 and Sw3. The Inw and Sw for short period of irrigation gave values lower than the critical levels. Data revealed also, that the highest content of trace elements in all the studied soil sites was found in the surface layers of soils irrigated with polluted sources, (Table 7).

The trend of Pb followed: Inw > Sw6 > Sw3 > Sw2 > Mw> R. The highest values were 3.1 and 2.02 mg/kg in the surface and subsurface layers of soil irrigated with Inw. As for the different periods of application of Sw, its values were 1.84, 1.64 and 1.32 mg/kg for Sw2, Sw3 and Sw6 in the surface layer, respectively. Also, these values were 1.48, 1.5, and 1.06 mg/kg in the subsurface layer, respectively. In, Mw and R the values were 0.78, 0.7 and 0.5, 0.56 mg/kg in the surface and subsurface layers, respectively, (Table 7).

TABLE 7. DTPA extractable heavy metals of soil affected with the different water resources

Treatments	Depth (cm)	Pb	Ni	Fe	Zn	Mn	Cu
		(mg/kg)					
Sw2	0-30	1.32	0.50	4.34	0.70	5.28	0.44
	30-60	1.06	0.44	2.52	0.26	2.90	0.30
Sw3	0-30	1.64	0.62	6.80	0.80	7.18	0.50
	30-60	1.50	0.60	4.38	0.32	3.08	0.34
Sw6	0-30	1.84	0.94	10.24	1.04	11.28	0.60
	30-60	1.48	0.72	5.60	0.40	4.72	0.38
Inw	0-30	3.10	0.62	2.02	3.42	6.40	0.82
	30-60	2.02	0.56	1.88	0.34	5.06	0.44
Mw	0-30	0.78	0.34	1.88	0.44	2.06	0.28
	30-60	0.50	0.20	1.08	0.22	1.88	0.16
R	0-30	0.70	0.26	1.22	0.22	1.82	0.24
	30-60	0.56	0.18	1.06	0.20	1.34	0.14

Sewage waste application caused remarkable increase of Ni-DTPA. The values were 0.94, 0.62, 0.5 mg/kg and 0.72, 0.6, 0.44 mg/kg in Sw2, Sw3, Sw6 in the surface and subsurface layers, respectively. In general, the trend of Ni followed the order of Sw6 > Sw3 = Inw> Sw2 > Mw > R, Table 7.

It can also be noticed that, the Sw application increased the Fe-DTPA after the periods of application 6, 3, and 2 years. The Fe values were 10.24, 6.8 & 4.34 and 5.6, 4.88 & 2.52 Ing/kg in the surface and subsurface layers, respectively. The data showed that Fe-DTPA in the Inw was low like Mw and R. Generally, the trend of Fe- DTPA followed the order of Sw6> Sw3 > Inw> 5w2 > Mw> R, (Table 7).

The amounts of Zn-DTPA in the soil irrigated with industrial wastewater were generally higher than there irrigated from sewage wastewater after different period of application. The enrichment of these soils by metals is due to metals input with irrigation water. A high proportion of metal input is accumulated in topsoil. In general Zn-DTPA followed the order: Inw> Sw6> Sw3> Sw2 > Mw> R. The highest value of DTPA-Zn was 13.42 mg/kg for Inw, on the other hand, its values were 1.04, 0.8, 0.7 mg/kg after Sw in the surface layer after the periods of 6,3,2 years, respectively, (Table 7).

DTPA-extractable Mn increased as periods of sewage effluent application increased. Large amount of Mn accumulated in soil from sewage waste after period of6 years. General trend of Mn- DTPA followed the order: Sw6> Sw3 > Inw> Sw2 > Mw >R. The values were 11.28, 7.18, 5.28 & 6.4, and 4.72,3.08,2.9 & 5.06 mg/kg from sewage waste water after period of 6,3,2 years and Inw in the surface and subsurface layers, respectively, (Table 7).

DTPA-extractable Cu slightly increased from 0.44 to 0.6 mg/kg after 6 years of application. It can also be noticed that, due to the use of industrial waste water the DTPA-Cu represents the highest values 0.82 and 0.44 mg/kg in the surface and subsurface layer, respectively. In general, the trend of DTPA-Cu followed the order: Sw6 > Sw3 > Inw> Sw2> Mw> R, (Table 7).

Geostatistical analysis

Micro-variability of soil at the scale of individual fields have been studied by geostatisti cal methods (Webster, 1985 and Stein, 1991). The geostatistical analysis was carried out for DTPA- heavy metal in mgfkg (Fe, Zn, Mn, Cu, Ni, Pb) , electric conductivity (EC) , soluble sodium (Na^+) ; chloride (Cl^-) and sodium adsorption ratio (SAR) in the surface layer. Three semi-variogram model fitted the individual soil properties, (Table 8). The fitted models were exponential for DTPA-Fe and Cl^-; spherical for DTPA-(Zn , Mn & Ni) and Na^+, while DTPA-(Cu & Pb), E.C and SAR are Gaussian (Fig. 2 and 3). It is clear that the selected properties represent the highest nugget variance, which indicate their strong; spatial dependence and high inherited variability (Xu and Webster 1984 and Warrick *et al.* 1986). The sill variance illustrates the structural variance and the ranges, which show the spatial dependence over specific lag distance. The kriging map showed that the spatial and temporal variability of soil properties (Fig.4, 5 and 6).

The results of geostatistcal analysis demonstrate that spatial patterns may vary among several soil parameters, scales and times. The results illustrate some useful concepts relevant to site-specific management. Variography can be a useful tool for designing effective soil sampling strategies, for establishing the dimensions of application zones and for screening soil variables for use in site-specific applications.

TABLE 8 . Geostatstical analysis and its parameters.

Variables	Model	Spatial Parameters			R^2
		Co	Co+ C	A°	
DTPA- Fe, mg/kg	Exponential	1.06	2.93	5.73	0.51
DTPA- Zn, mg/kg	Spherical	0.40	0.50	2.07	0.76
DTPA- Mn, mg/kg	Spherical	4.00	4.82	7.55	0.62
DTPA- Cu, mg/kg	Gaussian	0.33	0.48	14.24	0.44
DTPA- Ni, mg/kg	Spherical	0.09	0.19	6.82	0.40
DTPA- Pb, mg/kg	Gaussian	0.149	0.22	3.41	0.80
E.C (dS/m)	Gaussian	4.03	6.48	3.82	0.43
Na^+ (meq/l)	Spherical	101.1	162.2	3.82	0.68
SAR	Gaussian	0.06	0.066	1.65	0.45
Cl^- (meq/l)	Exponential	110.0	141.1	3.82	0.80

Conclusion

Results indicated that the of tested variables on some soil characteristics could be summarized as follows:

(a) Physical properties: aggregate water stability and structure coefficient increased due to the application of sewage and industrial water and decreased with agricultural drainage water. The same trend was noticed for soil bulk density, soil hydraulic conductivity, soil penetration coefficient and soil moisture content.

(b) Chemical properties: the pH values decreased by the application of sewage and industrial water and slightly increased with agricultural drainage water. The EC values increased with tested waters with marked increase due to agricultural drainage water. The values of Mn, Cu, and Ni were above the critical level for the tested low quality waters. While, Pb and Zn values were close to the critical level. Fe contents for soil samples taken after 3 and 6 years of wastewater application exceeded the critical level. Increasing the period (temporal variability) of using the low quality water for irrigation resulted in a significant increase in the heavy metal contents in the soil samples.

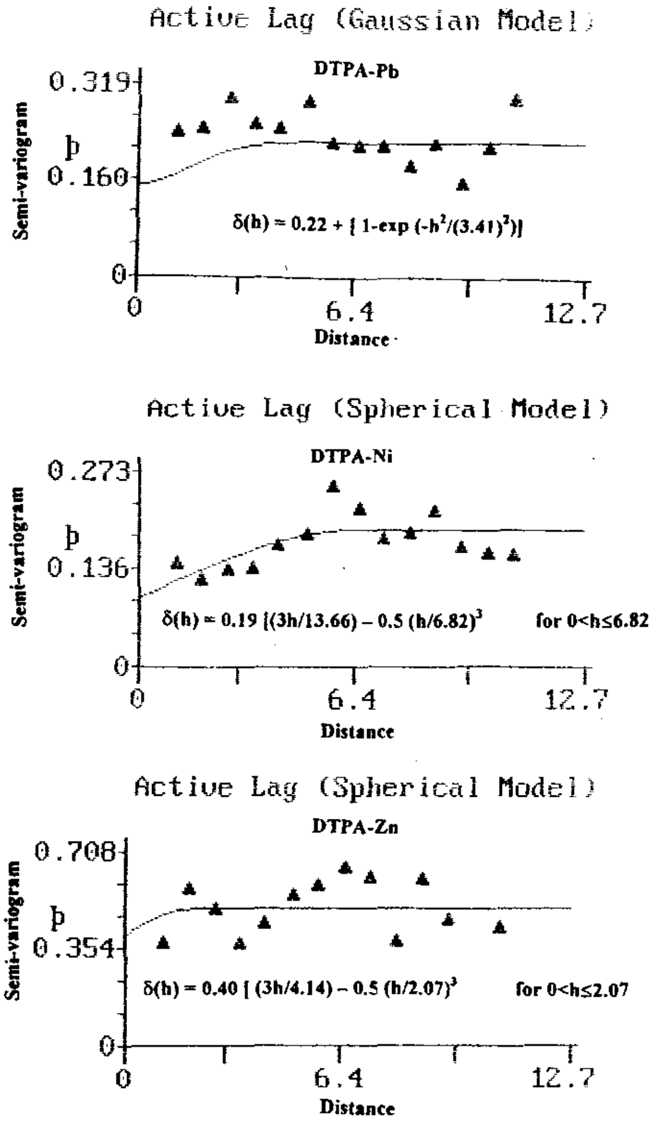

Fig. 2. Semi-variogram models of DTPA-(Pb, Ni & Zn).

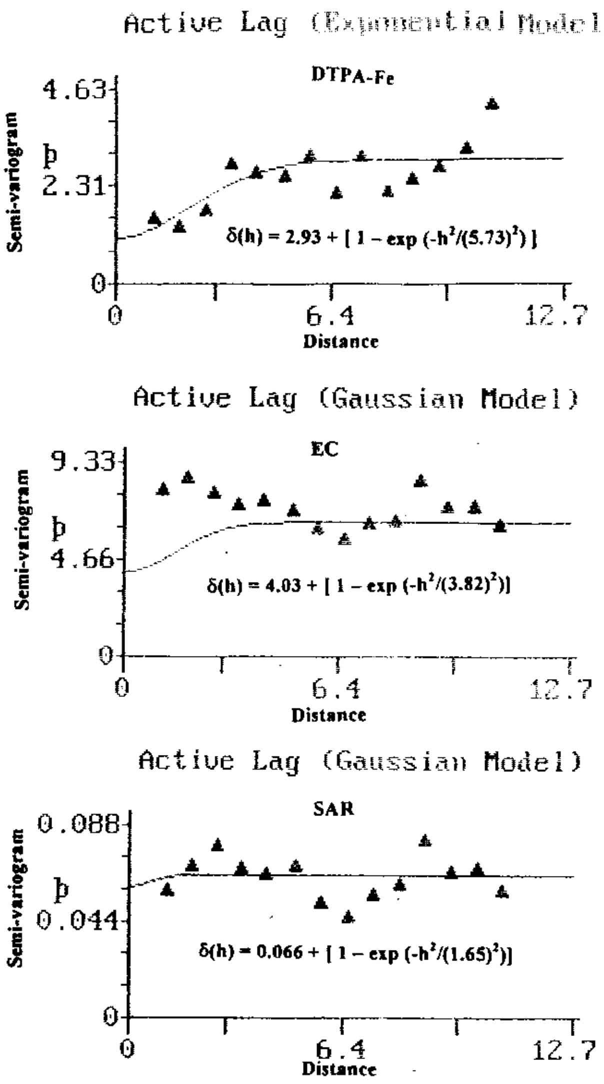

Fig. 3. Semi-variogram models of DTPA- Fe,EC and SAR.

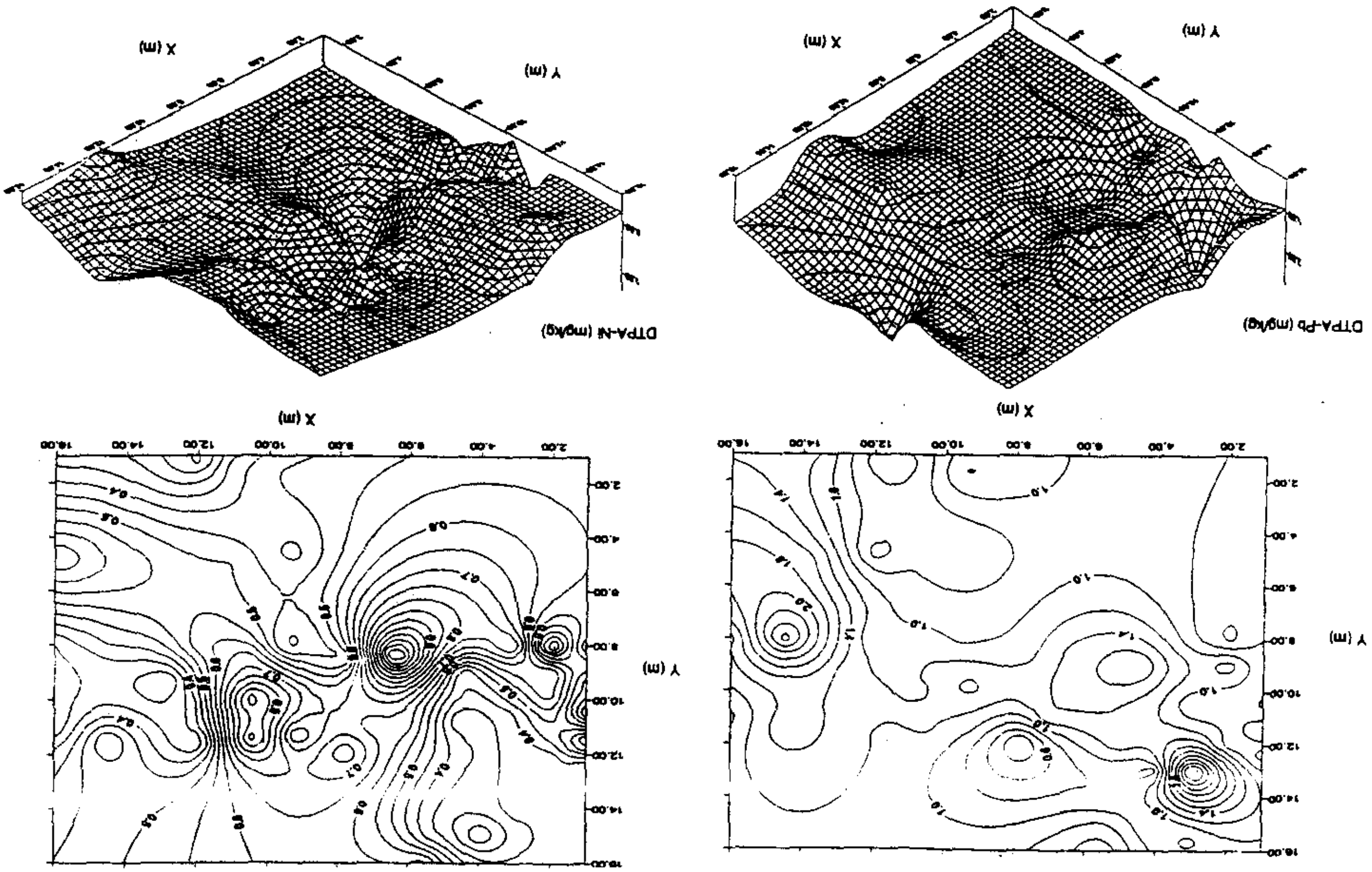

Fig. 4. Kriging map and 3 D of DTPA-Pb and Ni for the surface layer.

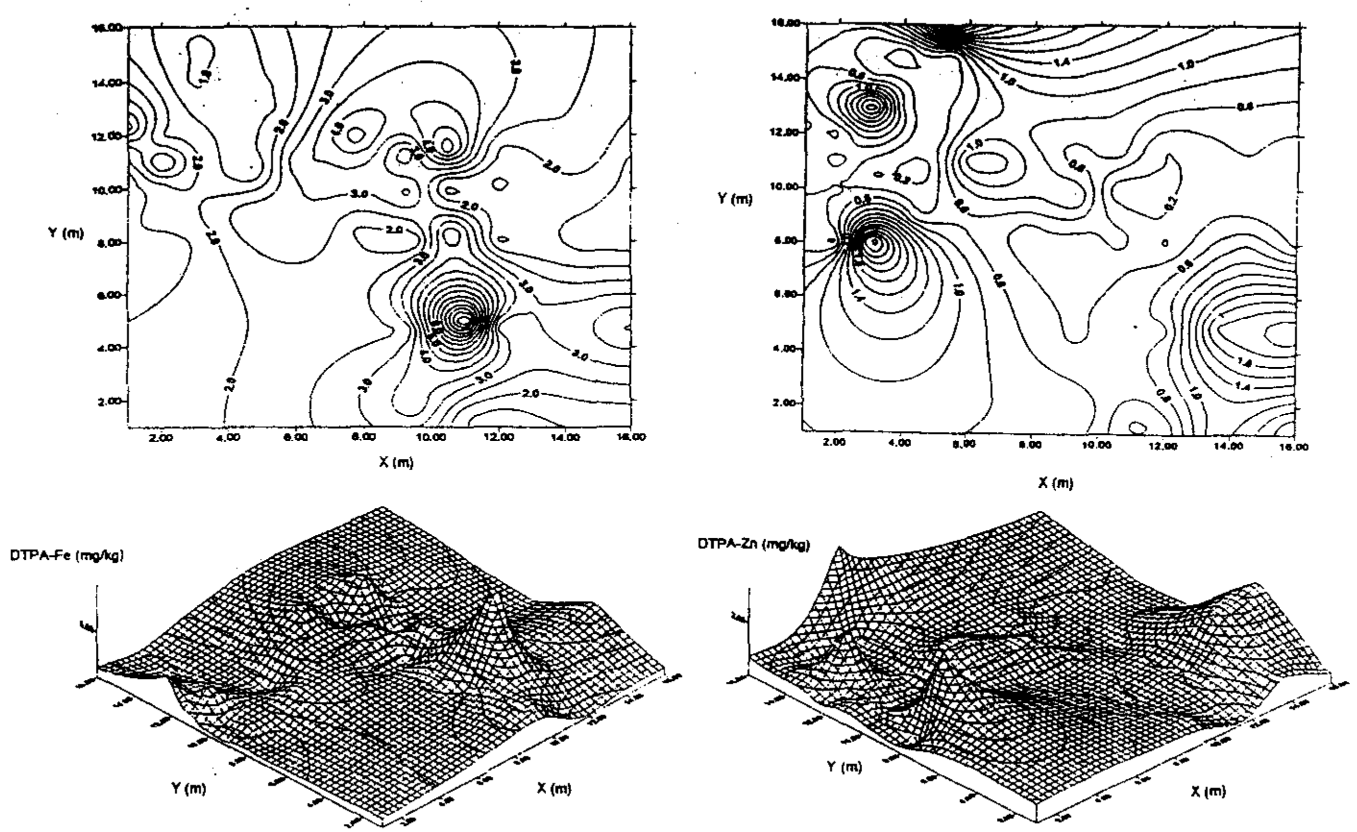

Fig. 5. Kriging map and 3 D of DTPA-Fe and Zn for the surface layer.

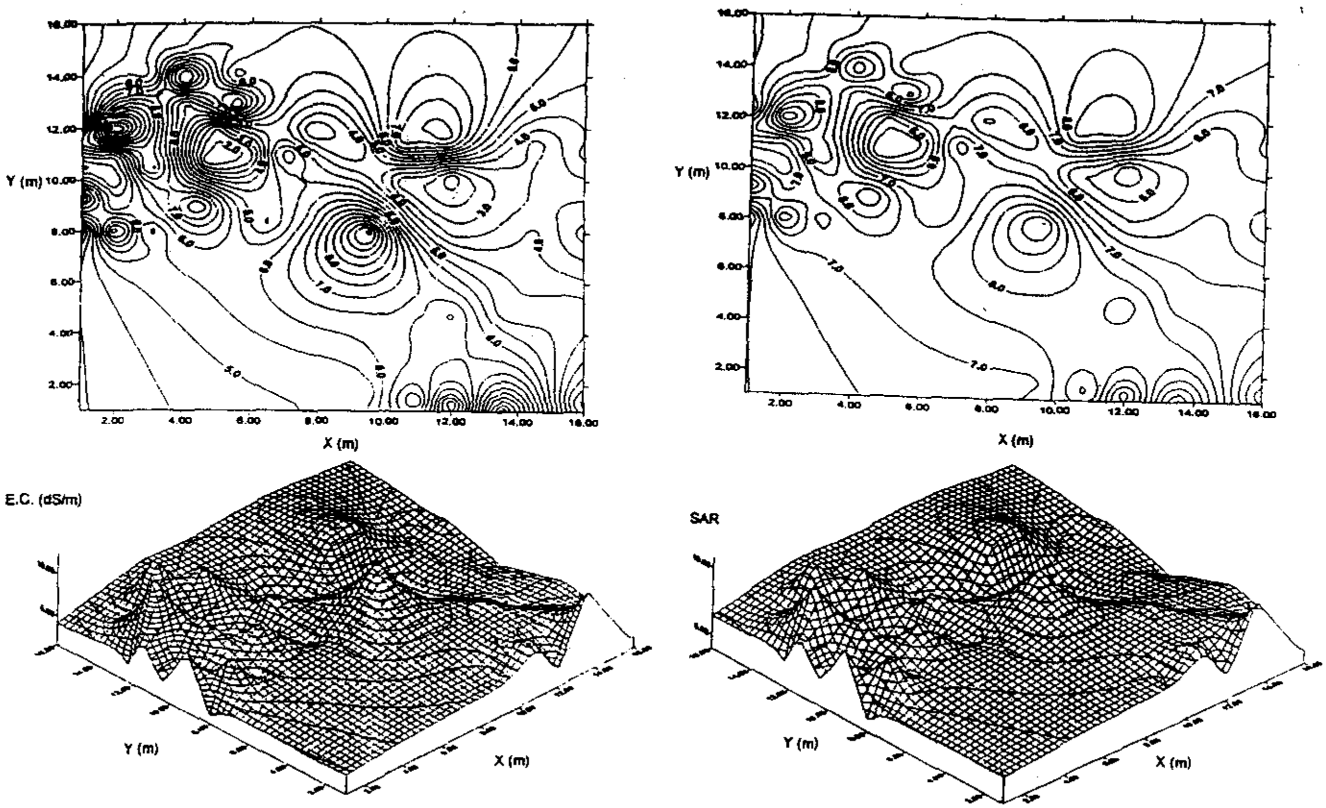

Fig. 6. Kriging map and 3 D of EC and SAR for the surface layer.

Results of geostatistical analysis to quantify the degree of spatial variability and dependence in surface layer indicated a semi-variogram model. Spatial variations of soil properties tend to be correlated over space. Semi-variogram model parameters showed that EC and heavy metals have the highest nugget variance, which indicated their strong spatial dependence and high inherited variability. The kriging maps showed the kriged distribution of the studied properties using the results of semi-variogram analysis.

References

Abdel-Sabour, M.F., Ismail, A.S. and Abou Naga, H. (1996) Environmental impact of Cairo sewage effluent on El-Gabal El-Asfer Farm. *Egypt J. Soil Sci.* **36**(1-4), 329.

Abdel-Sabour, M.F. Sand W., Massoud, M.A. and El-Kholl, A.F. (1988) Study of soil and plant pollution with some heavy metals. *Proc. The first Nat. Conf on Environ. Studies and Res.* **2**, 679.

Bahri, A. (1988) Present and future state of treated wastewaters and sewage sludge in Tunisia. Presented at *Regional Seminar on Wastewater Reclamation and Reuse*, 11 - 16 December, 1988, Cairo.

Black,C.A.,(Ed.) (1965) *Methods of Soil Analysis*, Part 2. Am. Soc. of Agron. Monograph No.9, ASA, Madison, Wisc., USA.

Bieloria, H., Valsman, I. and Feigin, A. (1984) Drip irrigation of cotton with treated municipal effluent I. Yield response. *J. Environ. Qual.* **13**, 231.

Cambell, N.F., Miller, R.W., Reynolds, J.H. and Schreeg, T.M. (1983) Alfalfa, sweetcorn, and wheat responses to long term application of municipal wastewater to cropland. *J. Environ. Qual.* **2**, 243.

Day, A.D., McFadyen, J.M., Tuker, T.C.and Cluff, C.B. (1981) Effect of municipal wastewater on the yield and quality of cotton. *J.Environ. Qual.* **10**,47.

El-Gamal, I.M. (1980) Evaluation of Cairo liquid sewage sludge applied to soil with special consideration to its heavy metal content. *M.Sc. Thesis*, Fac. of Agric., Ain Shams Univ., Egypt.

El-Khames, M.E.M. (1982) Study of wastewater application effects on different characteristics of soils and applied wastewater. *M.Sc. Thesis,* High Institute of Public Health, Alex. Univ., Egypt.

El-Shafei, Y.Z. and Ragab, R.A.(1975) Soil surface sealing caused by rain drop impact. *Egypt. J. Soil Sci.,* **16,** 47.

El-Sokkary, I.H. and Sharaf, A.I. (1996) Enrichment of soils and plants irrigated by wastewater by zinc and cadmium. *Egypt J. Soil Sci.* **36,** (1-4), 219.

Gomma, H. El.Z. (1989) Effect of Alexandria wastewater and sludge application on physical properties and crops of newly reclaimed soils. *M.Sc. Thesis,* Fac. of Agric., Alex. Univ., Egypt.

Gamma Design (1991) *GS^+ ; Geostatistical for Biological Science Version 1.1User's Manual.* Plaivwell, Mi, USA.

Ibrahim, S.A. (1964) Studies on the size distribution of water stable aggregates in the soils of the Nile Delta. *M.Sc. Thesis,* Fac. of Agric., Ain-Shams Univ., Cairo, Egypt.

Issaka, E.D. and Srivastava, R.M. (1989) *An Introduction to Applied Geostatistics.* Oxford University Press.

Klute, J. (1965) Laboratory measurement of hydraulic conductivity of saturated soils. (c.f. Black *et al.,* 1965, *Methods of Soil Analysis,* part 1: 219).

Lindsay, W.L. and Norvell, W.A. (1978) Development of DTPA soil test for Zn, Fe, Mn, and Cu. *Soil Sci. Soc. Am. J.* **42,**421.

Page, A.L., Miller, R.H. and Keeney (1982) *Methods of Soil Analysis,* Part 2, ASA, SSSA, Madison, Wisconsin, USA.

Rabie, F., Fawzy, A., Khader, M. Y. and Hussein,W. (1996 a) Contents of biogenic and non-biogenic heavy metals in El-Saff soils as related to different pollution sources. *Egypt. J.Soil Sci.* **36** (1-4), 165.

Rabie, F., Khader, M. Y., Rashad, I.F., Fawzy, A. and Hussein,W. (1996 b) Heavy metals distribution in the different particle sizes of soils irrigated from polluted sources. *Egypt . J. Soil Sci* **36** (1-4), 179.

Richards, L.A. (1954) *Diagnosis and Improvement of Saline and Alkali Soils.* U.S. Dep. Agric Hand Book 60,U.S. Govt. Printing Office, Washington.

Stein, A. (1991) Spatial interpolation. *Ph.D. Thesis,* Agricultural University Wageningen, The Netherlands.

Surfer, (1994) *User' S manual , copyright ,* Golden software version 5.

Warrick, AW. , Myers, D.E., and Nielson, D.R. (1986) Geostatistical methods applied to soil science in: A. Kkwte (Ed.). *Methods of Soil Analysis,* Part 1, *Physical and Minerological Methods,* 2nd ed., *Agronomy,* **9,** 3-1.

Webster, R. (1985) Quantitative spatial analysis of soil in the field. *Advances in Soil* Sci. **3,** 1.

Xu, J. and Webster, R.C. (1984) A geostatistical study of topsoil properties in Zhangwu country, *China. Catena.* **11,**13.

Yoder, R.E. (1936) A direct method of aggregate analysis of soils and a study of the physicol nature of erosion losses. *J. Am. Soc. Agron.* **28,** 337.

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الإختلافات الفراغية والزمنية للتربة تحت الاستخدام الآمن لمياه رى منخفضة الجودة بمنطقة برج العرب - مصر

هانى محمد رمضان ومحمد عصمت أنور الفيومى
معهد بحوث الأراضى والمياه والبيئة ، مركز البحوث الزراعية ، الجيزة ، مصر.

تم إجراء دراسة مقارنة لتقييم الاستخدام الآمن لعدة مصادر مختلفة لمياه رى منخفضة الجودة بمزرعة محطة الصرف الصحى بمدينة برج العرب الجديدة - الساحل الشمالي الغربى - مصر خلال شهر مارس ١٩٩٩ .وتمثلت هذه المصادر فى مياه صرف صحى معالج تم استخدامها في الرى لفترات زمنية ٦ ، ٣ ، ٢ سنوات ، مياه صرف صناعى معالج تم استخدامهالمدة عام واحد، مياه رى مخلوطة (مياه نيلية + مياه صرف زراعى من ترعة بهيج)، مياه أمطار كمصدر للمقارنة .

وكانت أهم النتائج المتحصل عليها كما يلى :

أولا : الخواص الطبيعية للتربة :

زيادة ثبات الحبيبات المركبة مائيا وكذلك معامل البناء مع زيادة فترات استخدام تلك المياه فى الرى ، مع اختلاف اثر نوعية مياه الرى كما يلى :

مياه صرف صحى (٦ سنوات) >مياه صرف صحى (٣ سنوات)> مياه صرف صحى (٢ سنة) > مياه صرف صناعى > مياه أمطار > المياه المخلوطة.

ولوحظ بنفس الاتجاه انخفاض قيم الكثافة الظاهرية للتربة وزيادة قيم معامل التوصيل الهيروليكى وكذلك المحتوى الرطوبى للتربة. كما لوحظ أيضا زيادة قيم معامل الاختراق فى الأراضى المعاملة كما يلى : مياه صرف صناعى > مياه صرف صحى (٦ سنوات) > مياه صرف صحى (٣ سنوات) > مياه صرف صحى(٢سنة) > مياه الأمطار > المياه المخلوطة .

ثانيا : الخواص الكيمائية للتربة :

- انخفاض قيم رقم الحموضة والقلوية فى الأراضى المعاملة بتلك المياه كما يلى : مياه صرف صحى (٦ سنوات) > مياه صرف صناعى > مياه صرف صحى (٣ سنوات) > مياه صرف صحى (٢ سنة) > مياه الأمطار > المياه المخلوطة.

- ارتفاع قيم التوصيل الكهربائى كما يلى: المياه المخلوطة > مياه الصرف الصناعى > مياه الصرف الصحى (٦ سنوات) > مياه الصرف الصحى (٣ سنوات) > مياه الصرف الصحى (٢ سنة) > مياه الأمطار.
- زيادة صلاحية عناصر الرصاص والزنك والحديد كما يلى : مياه صرف صناعى > مياه الصرف الصحى (٦ سنوات) > مياه الصرف الصحى (٣ سنوات) > مياه صرف صحى (٢ سنة) > المياه المخلوطة > مياه الأمطار .
- زيادة صلاحية عناصر النيكل والمنجنيز والنحاس كما يلى: مياه صرف صحى (٦ سنوات) > مياه صرف صحى (٣ سنوات) > مياه صرف صحى (٢ سنة) > مياه صرف صناعى > المياه المخلوطة > مياه الأمطار.

ثالثا : التحليل الفراغى جيو أحصائى :

أوضح التحليل الآتى :

- موديل Semi-variogram لصلاحية عنصر الحديد والكلوريد الذائب كان Expontional model ، بينما كان Spherical model لصلاحية عناصر الزنك والمنجنيز والنيكل والصوديوم الذائب، وبالنسبة لصلاحية عناصر النحاس والرصاص والتوصيل الكهربائى ونسبة الصوديوم المدمص كان Gaussian model ثم رسمت خرئط Kriging لهذه الخصائص والتى كانت تمثل أعلى اختلافات فراغية. ولقد أوضح التحليل الجيو احصائى التغيرات الفراغية والزمنية على مستوى الاختلافات الدقيقة Micro-variability ويرجع ذلك لتعدد مصادر مياه الرى المختلفة النوعية .

أوضحت الدراسة أن استخدام مياه الصرف الصحى المعالجة لفترات طويلة ومياه الصرف الصناعى المعالجة قد أدى الي تحسين الخواص الطبيعية للتربة بينما أدى الى تدهور أو تغير نسبى فى بعض الخواص الكيميائية، بينما استخدام المياه المخلوطة قد ساعد على تدهور الخواص الكيميائية والطبيعية للتربة.