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Statistical Evaluation of Soil and Field Crops Pollution Due to Different Irrigation Water Qualities

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A COMPARATIVE field study was undertaken to evaluate the safe use of low quality water for irrigation of some clayey soils. The irrigation water sources were sewage wastewater (I), secondary treate sewage water (II), canal polluted water from human wastes and activities (III) and canal water (V), as a source of normal canal water for comparison (control). The results indicated that:

Highly significant differences were found between the composition of irrigation water used in studied area including; soluble salts, pH, SAR, macronutrients (N,P,K) micro-nutrients (Zn, Cu, Mn, Fe) and some heavy metals (Cd, Pb, Co, Ni, Cr, B) content.

Highly significant correlations (r) were found between the chemical composition of irrigation water used and soil chemical properties (whole profile), which predict the soil contamination due to irrigation with low quality water.

Highly positive significant correlations (r) were found between organic matter, calcium carbonate and soil salinity, available macro, micro-nutrients and some available heavy metals. Soil reaction has a highly negative significant effect.

Highly significant correlations (r) were found between the soil content of macro, micro-nutrients and heavy metals, and its accumulation in shoots of Berseem and shoots and grains of Zea maize. This statistical evaluation represents the expected hazards to human or animals health and pollution to the environment as a whole.

Therefore, to protect public health, the effluent should either be properly treated in advance before discharge it into the water ways before irrigation application, or its use restricted to certain crops. So, improperly treated wastewater not reach any part of a plant used for human or animals consumption.

Keywords: Irrigation water, Soil, Plant, Pollution, Nutrients, Heavy metals, Statistical analysis.

Egypt attached particular attention on the rational and most efficient use of all available conventional water resources through water saving irrigation approaches and also through optimal and sustainable use of non-conventional water sources, including drainage water and treated sewage water.

Reuse of sewage water may have potential adverse impacts on the environment largely depending on sewage water characteristic, the degree of purification, the method and location of reuse. Soil, ground water and surface water pollution are among the most important disadvantages of the sewage water reuse, as sequence plant production (Papadopoulos, 1995).

It is clear from many studies to date (1979-2000) that under the use of low quality water for irrigation, there is a potential affect on soil and plant as well as human and animals.

Soil contaminated with heavy metals can produce apparently normal crops that may be unsafe for human and animals consumption (Koke, 1979). These metals in most cases are accumulated in the plant tissue or grains and when the later are consumed by human or domestic animals may adversely effect their health (Abu ElRoos *et al.*, 1989).

Grigoryan (1990) showed that the continual irrigation with sewage water led to gradual increase in the accumulation of some heavy metals in the soil. The content of heavy metals in plants increases with increasing their concentration in the soil. A comparison of the accumulation of heavy metals by fruit and vegetables crops showed that in all plants, these metals increase with increasing heavy metals concentration in soil (Evans *et al.*, 1979, Truby and Raba 1990, Venter, 1993 and Abbas; 1993).

Wilke and Metz (1992) found that maize gave the highest biomass yield and was less sensitive to heavy metals pollution than other species. Leaves generally contained greater amounts of the heavy metals than stems; root contained 3-20 times more than above ground parts.

The enhancement of industrial activities led to an increase in heavy metals in the environment (soil, water and plants). These effects are related to dispose the wastes of some industrial plants to drains or canals. These wastes provide heavy metals to the environment, which affected badly soil properties (El-Kassas *et al.*, 1994). All heavy metals are aggressive environmental pollutants. They are easily taken up by plants and they are strong stress factors for plant metabolism. Heavy metals influence includes also disturbances in plant mineral nutrition by competition with other nutrients (Siedlecka, 1995).

Abdel Sabour and Rabie (2000) found in soils subjected to irrigation with domestic and industrial wastewater for long time (35 years) that vegetable plants species varied in their affinity to accumulate metals in their edible parts. Irrigation with different wastewater significantly increased the concentration of all tested metals (Fe, Mn, Zn, Cu, Co, Cd, Ni, and Pb) in vegetable plants especially the leafy species. These abnormal levels exceed the permissible metals intake as suggested by WHO.

The aim of this study is to evaluate the safe use of low quality water for irrigation and its effect on soil properties as well as some filed crops contamination.

Material and Methods

Field work

A comparative field study was undertaken during growing season (1997-1998) to evaluate the safe use of the low quality water for irrigation at Zenien area, El-Giza governorate, Egypt. Four locations were chosen differing in irrigation water sources, included: Sewage wastewater from Nahia drain (I), secondary treated sewage water from Zenien plant (II), canal polluted water with human wastes and activities from Abd El Aal canal (III), and canal water as control outside the polluted area (V). The studied soils are characterized by texture class of sand, 27%, silt 23% and clay 50%. The soil texture is clay. The tested crops were Berseem and Zea maize. A monthly water samples were collected from the different irrigation sources. Soil samples were taken from different locations at harvest time. Plant shoots and grains samples were taken from the same sites.

Laboratory analysis

- Chemical analysis for irrigation water and soil paste extracts were done according to Jackson (1973).
- Available macro; micro-nutrients and heavy metals, were extracting byAB-DTPA according to Soltanpour (1991) and determined by using ICP, 400.

- Available nitrogen forms were determined according to Markus *et al.* (1982), by using Technicon Auto Analyzer, method No.763-85 (GT) A.

Statistical analysis

Statistical analysis were done according to Snedecor and Cochran (1967).

Results and Discussion

Characteristics of irrigation water sources used

Data presented in Table 1 show the analysis of variance and LSD test of irrigation water used in the studied area. There is a highly significant difference between the sources of irrigation water including, EC_w , pH, SAR, macro and micro-nutrients and some heavy metals content in comparison with those of the canal water (control). The salinity vary from slight to moderate for different water sources in comparison with those of canal water (V) , which is considered non-saline and non polluted according to Ayers and Westcot (1985) .

In spite of the relatively high content of macro-nutrients, which are present in irrigation water used, yet they still within the permissible limits. NH_4 - N is exceed the safe limits according to Ayers and Westcot (1985). Phosphorus and potassium show a higher concentrations than the usual range in fresh canal water. It is worth to mention that there is no guidelines for P and K for interpretation water quality for irrigation. Thus, it could be considered from the point of view of fertilization as supplemental fertilizers to the soil in future (Papadopoulos and Stylianou, 1991).

The concentration of micro-nutrients (Zn, Mn, Cu and Fe), were in the safe limits except Mn content of canal polluted water. They exceed the safe limits according to the guidelines of National Academy of Sciences (1972).

Regarding the heavy metals which present in negligible amount can accumulate to toxic concentration in agnricultural food crops (Mclaughlin *et al.*, 1996). data show that its concentration in irrigation water used are in the safe limits except Cd and Co content, which are exceed the safe limits by National Academy of Sciences (1972) for all sources of irrigation water used except the control.

TABLE 1. Analysis of variance and LSD test of different irrigation water (mean values) used of the studied area.

Irrigation Sources	EC dS/m	pH	SAR	mg/L													
				NO_3	NH_4	P	K	Zn	Mn	Cu	Fe	Cd	Pb	Co	Ni	Cr	B
I	1.19	7.42	4.04	3.31	19.75	3.07	0.97	0.04	0.20	0.02	0.14	0.04	0.23	0.09	0.03	0.07	0.30
II	1.25	7.37	4.18	4.52	17.95	3.68	0.83	0.09	0.08	0.03	0.13	0.03	0.18	0.06	0.03	0.04	0.36
III	2.32	7.60	4.23	4.22	25.58	9.00	0.94	0.07	1.16	0.05	2.20	0.22	0.09	0.07	0.03	0.05	0.22
V	0.54	8.02	1.42	1.43	0.54	0.17	0.20	0.01	0.01	0.01	0.06	0.01	0.05	0.01	0.02	0.02	0.01
X_1-X_4	0.65**	-0.60**	2.62**	1.88*	19.21**	2.90	0.77**	0.03	0.19	0.01	0.08	0.03	0.18	0.08*	0.01**	0.05**	0.29**
X_2-X_4	0.71**	-0.83**	2.76**	3.09**	17.41**	3.51*	0.63**	0.08*	0.07	0.02	0.07	0.02	0.13	0.05	0.01**	0.02*	0.35**
X_3-X_4	1.78**	-0.42**	2.81**	2.79**	25.04**	8.83**	0.74**	0.06*	1.15**	0.03	2.14**	0.21	0.04	0.06	0.01**	0.03*	0.21*
LSD 0.05	0.326	0.293	1.769	1.452	3.539	3.331	0.049	0.056	0.820	0.046	0.335	0.285	0.213	0.089	0.0126	0.020	0.209
0.01	0.442	0.397	2.398	1.968	4.796	4.514	0.066	0.076	1.111	0.062	0.454	0.386	0.288	0.121	0.0171	0.027	0.284

Soil properties affected with low quality irrigation water used

Statistical analysis presented in Table 2 show Pearson correlation coefficient (r) with probability between chemical composition of irrigation water used and soil extraction (whole profile), for both Berseem and Maize plots. A highly significant correlation was found predicting the potential soil contaminating capacity due to the long term application of different water qualities. It could be concluded that using low quality water for irrigation is associated with an increase of EC_{ex} macro and micronutrients (N, P, K , Zn, Cu, Mn and Fe) and some heavy metals (Cd, Pb, Co, Ni, Cr and B). This is mainly due to the chemical composition of the irrigation water. Where heavy metals content don't exist in soluble forms in such water for a long time, they are presented mainly as suspended colloids or fixed by organic and mineral substances as well as accumulation of organic matter in the soil. In addition, slow mobility of these elements from the top soil layers to the deep ones. Generally, the transformation, mobilization, and immobilization of trace metals in soil depend on the type of metals soil, and geomorphology of the area as well as the dissolved constituents (Cruanas, 1992).

Statistical analysis presented in Tables 3 and 4 show Pearson correlation coefficient (r) with probability between pH, some soil components and soil chemical composition of Berseem and Maize plots. A highly positive significant correlation is found between organic matter as well as calcium carbonate and soil salinity, available macro, micro-nutrients and some available heavy metals content in the studied soil for both Berseem and Maize plots. Soil reaction (pH) has a highly negative significant correlation. This is mainly due to the release of organic acid during organic matter degradation and microbial activity in the soil as a result of using low quality water in the studied area. The decrease in soil reaction is increasing the solubility of micro-nutrient and some heavy metals in soil.

Plant uptake of elements as a result of using polluted water for irrigation

Statistical analysis presented in Table 5 show Pearson correlation coefficient (r) with probability between available macro, micro-nutrients and some heavy metals content of the soil and the studied field crops (shoot & grain) at the studied area under irrigation with low quality water.

TABLE 2. Pearson correlation coefficient (r) with probability between chemical composition of both irrigation water and soil extraction (Whole profile.).

Irrigation water / Soil	EC	pH	NO_3	NH_4	P	K	Zn	Mn	Cu	Fe	Cd	Pb	Co	Ni	Cr	B
Berseem plots	0.351	0.601**	0.447*	0.805**	0.273	0.365	0.461*	0.102	0.535**	0.275	0.961**	0.506**	0.493**	0.519**	0.695**	0.543**
	0.850	0.001	0.025	0.000	0.187	0.073	0.020	0.629	0.006	0.184	0.01	0.01	0.012	0.009	0.000	0.005
Maize plots	0.425*	0.531**	0.447*	0.805**	0.275	0.358	0.460*	0.102	0.535**	0.275	0.867*	0.520**	0.230	0.705**	0.586**	0.498**
	0.034	0.006	0.025	0.000	0.184	0.079	0.021	0.626	0.006	0.183	0.035	0.008	0.269	0.000	0.002	0.011

TABLE 3. Pearson correlation coefficient (r) with probability between pH, some soil components and soil chemical composition (Berseem plots).

Soil Components	EC	NO_3	NH_4	K	P	Zn	Mn	Cu	Fe	Cd	Pb	Co	Ni	Cr	B
pH	-0.633**	-0.423*	-0.506**	-0.282	-0.30	-0.496**	-0.566**	-0.521**	-0.679**	-0.535**	-0.370	-0.619**	-0.592**	-0.626**	-0.705**
	0.001	0.035	0.010	0.172	0.145	0.01	0.003	0.008	0.000	0.006	0.069	0.001	0.002	0.001	0.000
O.M	0.280	0.659**	0.285	0.544**	0.563**	0.730**	0.695**	0.442*	0.306	0.319	0.713**	0.550**	0.159	0.362	0.252
	0.175	0.000	0.168	0.005	0.003	0.000	0.000	0.027	0.137	0.120	0.000	0.004	0.448	0.075	0.218
$CaCo_3$	0.228	0.187	0.103	0.560**	0.285	0.438*	0.467*	0.412*	0.271	0.575**	0.569**	0.511**	0.348	0.408*	0.445*
	0.274	0.369	0.625	0.004	0.167	0.020	0.019	0.041	0.189	0.003	0.003	0.009	0.088	0.043	0.026
Clay	-0.433*	0.029	-0.331	-0.061	-0.016	-0.055	-0.111	-0.375	-0.461*	-0.384	-0.164	-0.348	-0.482*	-0.466*	-0.500**
	0.030	0.891	0.106	0.773	0.941	0.795	0.600	0.064	0.021	0.058	0.433	0.088	0.015	0.019	0.011
Silt	-0.298	-0.154	-0.200	-0.080	-0.18	-0.199	-0.22	-0.03	-0.212	-0.155	-0.144	-0.138	-0.229	-0.203	-0.160
	0.148	0.462	0.337	0.690	0.389	0.341	0.28	0.887	0.309	0.460	0.493	0.511	0.272	0.331	0.446
Sand	0.579 *	0.063	0.429	0.114	0.122	0.168	0.233	0.380	0.561**	0.455*	0.243	0.413*	0.584**	0.557**	0.568**
	0.002	0.766	0.032	0.587	0.562	0.421	0.263	0.061	0.004	0.022	0.242	0.040	0.002	0.004	0.003

TABLE 4. Pearson correlation coefficient (r) with probability between pH, some soil components and soil chemical composition (Maize plots).

Soil components	EC	NO_3	NH_4	K	P	Zn	Mn	Cu	Fe	Cd	Pb	Co	Ni	Cr	B
pH	-0.428*	-0.328	-0.628**	0.234	-0.259	-0.313	-0.458*	-0.476*	0.664**	-0.530**	-0.422*	-0.087	-0.628**	-0.66**	-0.732**
	0.033	0.109	0.001	0.260	0.210	0.128	0.020	0.016	0.000	0.006	0.036	0.680	0.001	0.000	0.000
O.M	0.421*	0.748**	0.373	0.787**	0.821**	0.808**	0.713**	0.720**	0.436*	0.539**	0.799**	0.280	0.520**	0.358	0.284
	0.030	0.000	0.066	0.000	0.000	0.000	0.000	0.000	0.030	0.005	0.000	0.175	0.008	0.078	0.169
$CaCo_3$	0.487**	0.356	0.295	0.773**	0.552**	0.609**	0.652**	0.610**	0.488**	0.491**	0.717**	0.330	0.579**	0.438*	0.527**
	0.014	0.080	0.153	0.000	0.004	0.001	0.000	0.001	0.013	0.013	0.000	0.108	0.002	0.029	0.007
Clay	-0.526**	0.029	-0.332	-0.072	-0.020	-0.055	-0.11	-0.376	-0.461*	-0.494**	-0.293	-0.288	-0.424*	-0.620**	-0.485**
	0.007	0.892	0.105	0.733	0.926	0.794	0.601	0.064	0.020	0.012	0.155	0.163	0.035	0.001	0.014
Silt	-0.129	-0.154	-0.200	-0.076	-0.179	-0.199	-0.222	-0.03	-0.212	-0.059	-0.128	-0.163	-0.191	-0.202	-0.373
	0.539	0.461	0.337	0.718	0.392	0.341	0.286	0.887	0.310	0.779	0.543	0.435	0.360	0.333	0.066
Sand	0.579**	0.063	0.429*	0.120	0.125	0.169	0.232	0.381	0.056**	0.512**	0.357	0.382	0.521**	0.704**	0.669**
	0.002	0.765	0.032	0.567	0.551	0.421	0.264	0.060	0.004	0.009	0.080	0.060	0.008	0.000	0.000

TABLE 5. Pearson correlation coefficient (r) with probability between both soil and plant elements content.

Soil & plant element content		N	P	K	Zn	Mn	Cu	Fe	Cd	Pb	Co	Ni	Cr	B
Berseem	Shoots	0.744^{**}	0.612^{**}	0.427^{*}	0.542^{**}	0.545^{**}	0.562^{**}	0.828^{**}	0.505^{**}	0.468^{**}	0.652^{**}	0.357	0.865^{**}	0.904^{**}
		0.000	0.001	0.020	0.005	0.005	0.003	0.000	0.010	0.018	0.000	0.080	0.000	0.000
Maize	Shoots	0.272	0.182	0.009	0.415^{*}	0.461^{*}	0.657^{**}	0.754^{**}	0.511^{**}	0.453^{*}	0.168	0.846^{**}	0.772^{**}	0.915^{**}
		0.189	0.383	0.968	0.039	0.021	0.000	0.000	0.009	0.023	0.422	0.000	0.000	0.000
	Grains	0.641^{**}	0.422^{*}	0.404^{*}	0.353	0.835^{**}	0.610^{**}	0.386^{**}	0.663^{**}	0.461^{*}	0.213	0.741^{**}	0.713^{**}	0.459^{**}
		0.001	0.036	0.045	0.084	0.000	0.001	0.000	0.000	0.020	0.308	0.000	0.000	0.000

A highly significant correlation was found between the soil content of macro, micro-nutrients and some heavy metals and its accumulation in shoots of Berseem and shoots and grains of Zea maize,due to the use of low quality water for irrigation. It is noticed that the translocation from the soil to the shoots or grains differ from one element to another. However, the transport of trace metals in soil and their uptake by plants are governed by their mobility (Cottenie,1980). In general, trace metals are less mobile and thus less bio-available in soil with higher organic matter and clay content (Cottenie *et al.*, 1983). The data clearly indicated that Berseem or Maize tend to accumulate these metals, in their shoots or grains, and when it exist in such toxic levels in the food chain, it represents a hazard to human and animals health (Bohan *et al.*, 1979).

The prolonged effects of using low quality water such as the wastewater used for irrigation in the study polluted area reflected in an increase in heavy metals accumulation in soil and plant. Therefore, the success of using that water depend greatly on treating this water, adopting appropriate strategies aimed to maintaining soil productivity and safe guarding public health and environment.

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التقييم الإحصائى لتلوث التربة ومحاصيل الحقل بالرى بمياه منخفضة الجودة

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أجريت دراسة حقلية مقارنة لتقييم الاستخدام الآمن لمياه رى منخفضة الجودة وتأثيرها على خواص التربة الطينية ومحصول البرسيم والذرة بمنطقة زنين بمحافظة الجيزة. وأشارت التحليلات الإحصائية للنتائج التالية:-

١- وجدت فروق عالية المعنوية بين مصادر الرى المختلفة المستخدمة في كل من التركيب الكيميائى لها ورقم الحموضة ومحتواها من العناصر الكبرى (النيتروجين - الفوسفور - البوتاسيوم) والعناصر الصغري (الزنك - النحاس - المنجنيز - الحديد) وكذلك محتواها من العناصر الثقيلة (الكادميوم - الرصاص - الكوبالت - النيكل - الكروميوم - البورون).

٢- وجد ارتباط موجب عالي المعنوية (r) بين محتوى المياه المستخدمة من هذه العناصر تحت الدراسة وتركيزها فى التربة مما يدل على تلوثها نتيجة استخدام مثل هذه النوعية المنخفضة الجودة.

٣- وجد ارتباط موجب عالي المعنوية (r) بين كل من المادة العضوية وكربونات الكالسيوم في التربة وكل من التوصيل الكهربى للأملاح ومحتواها الذائب من العناصر تحت الدراسة وكان لرقم تفاعل التربة ارتباط سالب المعنوية مع هذه العناصر.

٤- ومن التقييم الاحصائى وجد أن تلوث مياه الرى وانخفاض جودتها بمثل هذه العناصر أدى الى تلوث التربة ومن ثم النبات، فقد وجد ارتباط عالى المعنوية (r) بين التركيز الذائب لهذه العناصر فى التربة وتركيزها فى قش محصول البرسيم وقش وحبوب محصول الذرة مما يعكس الأثر الضار على كل من الانسان والحيوان وتلوث البيئة.

وعلى ذلك فالحفاظ على الصحة العامة للإنسان والحيوان يتطلب معالجة متقدمة لمياه الصرف الصحى قبل استخدامها فى الرى ومنع إلقاء المخلفات الآدمية فى الترع والمجارى المائية أو استخدام هذه النوعية من المياه بطريقة آمنة لزراعة محاصيل معينة لا يستخدمها الإنسان أو الحيوان فى غذائه.