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RISKS OF PROLONGED DRAINAGE WATER USE IN CLAY SOILS IN NORTH DELTA, Egypt

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ABSTRACT

Two clay soils differed in their irrigation water resources were chosen and wheat (Sakha 61 variety) was planted during 2002/2003 season. The first soil (soil 1) usually irrigated with Nile water, while the second (soil 2) located in the terminal end of irrigation canal and irrigated with drainage water 10 years ago. The objectives were subjected to look upon and evaluate the effects of long-term irrigation with marginal drainage water on some soil chemical and physical proprieties, wheat growth, yield and heavy metals content of soil and wheat plants.

The obtained results showed that long-term reuse of marginal drainage water in irrigating (soil 2) resulted in a remarkable increase in soil salinity and sodicity as compared to soil 1. These values slightly increased more after wheat harvest than before planting. Total water stable aggregates (TWSA) > 0.25 mm, mean weight diameter (MWD), optimum size of aggregation (OSA %), structure coefficient (SC) and aggregation index (AI) were lower in soil (2) than soil (1) before planting. These values decreased after wheat harvest and the reduction was more pronounced in soil (2). DTPA-extractable micro-nutrients (Fe, Mn and Cu) and heavy metals (Pb, Cd and Ni) recorded higher values in soil (2) than soil (1) before wheat planting and slightly increased in soil (2) after wheat harvest.

Data also showed that wheat growth parameters and yield component such as number of tillers, number of spikes, maximum growth dry weight, biological yield, straw yield, grain yield/plant were markedly reduced in soil (2). The heavy metals (Fe, Mn, Cu, Pb, Cd and Ni) content (mg/kg dry matter) of wheat straw and grains increased in soil (2) than soil (1) and were higher in straw than grains. Special soil and water management practices should be followed when the farmers were obliged to reuse marginal drainage water for irrigation to reduce the hazard effects on soil, plant growth, yield quantity and quality, as well as, mankind health.

INTRODUCTION

In Egypt, the population increased rapidly while the water resources are limited. Consequently; to meet the increasing demands for foods; improving irrigation system, increasing water use efficiency and reusing of drainage water for irrigation is a must.

In many parts of north Delta, farmers are obliged to reuse drainage water for irrigation especially in the terminal ends of irrigation canals. Use of saline water may result in reduction of crop yield, meanwhile, sodic waters may cause deterioration in the physical properties of soils, (Ramadan, S.A. *et al.,* 1989). On the other hand, use of such water irrigation may be considered the major source for heavy metals to the soil and plant. These metals are taken up from soils and bioaccumulated in crops, causing damage to plants when reach high levels and under certain conditions are becoming toxic to human and animals fed on these metals enriched plants (El-Sokkary and Sharaf, 1996). The rate and extent of the ions movement within plants depend on the metal concerned, the plant organ and the age of plant (Alloway, 1995). Chaney and Giordano (1977) classified Mn, Zn, Cd, B and Se as elements which were readily translocated to the plant tips, Ni, Co and Cu were intermediate and Cr, Pb and Hg were translocated to least extent.

The present investigation was carried out to study the effects of long-term irrigation with marginal drainage water on some chemical and physical properties of clay soils in relation to wheat growth, yield and uptake of heavy metals.

MATERIALS AND METHODS

Two alluvial clay soils differed in their irrigation water resources in Sedi-Salem district, Kafr El-Sheikh governorate were chosen. The first soil (soil 1) irrigated with Nile water. The second one (soil 2) located in the terminal end of irrigation canal and usually irrigated with drainage water for about 10 years ago. The selected soils was cultivated using wheat grains (*Triticum* sp.), Sakha 61 variety during 2002/2003 growing season. Tillage operation and other agronomic practices were followed as recommended. Soil samples were collected in 30 cm increment to a depth of 120 cm before wheat planting and after harvest. Total soluble salts (EC), soluble cations and anions in soil paste extract, pH and cation exchange capacity were determined according to Page (1982). Soil samples were also DTPA-extracted and Fe, Mn, Cu, Pb, Cd and Ni were determined using the atomic absorption spectrophotometer according to Lindsay and Norvell (1978). Aggregate size distribution in undisturbed soil samples were determined by Yoder (1936). Wheat straw and grains at harvest were collected for analysis. Dry ashing technique was used for sample digestion as described by Chapman and Pratt (1961) and the abovementioned heavy metals were determined according to Lindsay and Norvell (1978).

RESULTS AND DISCUSSION

1. Nile and drainage waters evaluation:

Chemical characteristics of Nile and drainage waters used for irrigation of wheat plants are shown in Table (1). Data showed that EC of Nile water was 0.46 dS/m and its SAR value was 0.87 and classified as (C_2-S_1) medium salinity low sodicity. While drainage (mixed) water EC was 2.96 dS/m with 7.0 SAR and classified as (C_4-S_1) very high salinity low sodicity, according to Richards (1969). The drainage water can not be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and a salt tolerant crop should be selected.

Regarding to heavy metals, data in Table (1) showed that the used drainage water contains higher concentrations of Fe, Mn, Cu, Pb, Cd and Ni metals compared with Nile Water. Although these concentrations still below the permissible levels according to London (1984), the drainage water could reach values of such metals over the permissible levels through the successive industrial and domestic effluents. Reuse of such drainage water for irrigation purposes may result in increasing the background levels of soil with time causing insidious effects to plant, animal and man, Ramadan *et al.* (1990). Results in Table (1) cleared also that the groundwater of soil (2) which irrigated with drainage water recorded higher values of the measured heavy metals than that irrigated with Nile water (soil 1).

Table (1): Ionic and heavy metals concentration of Nile, drainage and ground water.

Water	Anions meq/L			Cations meq/L				EC	SAR	Water	W.T
sample	HCO_3^-	Cl^-	$SO_4^=$	Ca^{+2}	Mg^{+2}	Na^+	K^+	dS/m		class	depth (cm)
Nile water* (soil 1)	2.00	4.00	1.74	4.24	3.12	1.42	0.16	0.46	0.87	C_1-S_1	
Drainage water* (soil 2)	8.00	22.00	6.84	6.48	9.88	20.00	0.48	2.96	7.0	C_4-S_1	
Ground water											
Soil (1)	5.80	20.0	6.78	4.24	5.96	22.21	0.18	2.58			135
Soil (2)	7.00	100.00	26.45	16.96	36.08	80.0	0.41	12.03			80

	Heavy metals concentrations in water samples (ppm)					
	Fe	Mn	Cu	Pb	Cd	Ni
Nile water* (soil 1)	1.841	0.067	0.015	0.214	0.012	0.081
Drainage water* (soil 2)	2.454	0.190	0.033	0.326	0.019	0.185
Ground water Soil (1)	2.813	0.145	0.025	0.330	0.017	0.107
Ground water (soil 2)	3.465	0.248	0.039	0.451	0.027	0.271
Permissible levels, London (1984)	5.0-20	0.2-10.0	0.2-5.0	5.0-10.0	0.001-0.05	0.2-2.0

2. Soil chemical characteristics:

Data in Table (2) show that, before wheat planting the soil irrigated with fresh water (soil 1) has ECe values varied from 1.94 to 3.52 dS/m with slight tendency to increase with increasing soil depth. These values slightly decreased in the soil layers to a depth of 90 cm and increased in the bottom layer (90-120) and 120-150 cm) after wheat harvest. While, the soil irrigated with drainage (mixed) water (soil 2), before wheat planting has high ECe values varied from 6.75 to 9.25 dS/m which increased with increasing soil depth. After wheat harvest the ECe values were slightly increased and varied from 8.29 to 10.48 dS/m. These results are in agreement with those obtained by Abou El-Soud (1987), Abo-Soliman *et al.* (1992) and Sobh *et al.* (1997). They reported that increasing salinity of applied water or using poor water quality of irrigation water caused an increase in soil salinity. Also, SAR values gave the same trend of ECe values (Table 2), El-Samanoudi (1992) reported that, increases in either salinity or SAR of irrigation water causes significant increase of soil ECe and SAR.

Table (2): Soil chemical characteristics before wheat planting and after harvest.

No. profile	Anions meq/L				Cations meq/L				EC	pH	SAR	O.M	CEC	ESP
Depth cm	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+	dS/m	(1: 2.5)		%	meq/ 100 g	
Before planting														
Soil (1)														
0-30	-	4.50	11.00	7.48	6.72	4.12	12.00	0.14	1.94	8.51	5.15	1.53	48.24	6.56
30-60	-	4.50	16.0	3.88	4.72	3.44	16.00	0.22	2.41	8.55	7.92	0.92	42.43	10.06
50-90	-	2.50	20.0	3.10	4.24	3.92	17.20	0.24	2.78	8.51	8.51	0.63		
90-120	-	4.00	20.0	4.92	6.20	4.44	18.00	0.28	2.78	8.45	7.79	0.78		
120-150	-	.0	30.0	4.81	8.48	5.80	25.20	0.37	3.52	8.37	9.44	0.65		
Soil (2)														
0-30	-	3.5	50.0	29.47	20.44	15.36	46.80	0.37	6.75	8.15	11.06	1.69	47.21	12.36
30-60	-	2.5	60.0	46.70	8.48	28.24	72.00	0.54	8.42	8.13	16.82	0.77	39.26	13.58
60-90	-	2.5	70.0	36.93	16.96	19.76	72.00	0.71	8.42	8.07	16.81	0.78		
90-120	-	2.0	80.0	28.62	16.96	19.76	73.20	0.70	9.25	8.08	17.02	0.66		
120-150	-	2.0	60.0	27.59	16.64	22.52	50.00	0.43	7.59	8.11	11.31	0.61		
After harvest														
Soil (1)														
0-30	-	4.0	10.0	3.33	5.36	1.80	10.00	0.17	1.53	8.54	5.29	1.16	48.24	8.60
30-60	-	4.0	14.0	1.97	4.24	1.88	13.60	0.25	2.08	8.65	7.77	0.78	42.43	14.85
60-90	-	4.0	20.0	3.89	4.24	3.92	19.40	0.33	2.68	8.52	9.60	0.70		
90-120	-	3.0	20.0	17.22	11.20	7.40	21.20	0.42	3.42	8.43	6.95	0.72		
120-150	-	3.5	20.0	18.05	8.48	5.80	26.80	0.47	3.89	8.40	10.04	0.85		
Soil (2)														
0-30	-	4.0	50.0	20.35	12.72	9.72	51.60	0.31	8.29	8.16	15.40	1.74	47.21	16.95
30-60	-	2.5	60.0	31.17	12.72	16.88	63.60	0.47	8.60	8.12	16.52	1.00	39.26	18.99
60-90	-	2.5	70.0	31.86	16.96	23.84	62.80	0.76	10.48	8.01	13.89	0.78		
90-120	-	2.5	60.0	36.74	8.48	20.08	70.00	0.68	8.60	8.06	18.52	0.72		
120-150	-	2.0	60.0	36.54	12.72	21.96	63.20	0.66	8.28	8.07	15.19	0.70		

O.M : Organic matter % CEC: Cation exchange capacity ESP: Exchangeable sodium percentage

Data in Table (2) also revealed slight decrease in soil pH values under soil irrigated with drainage water as compared to that irrigated with fresh one. In this concern, Mustafa *et al.* (1992), reported that increasing salinity level of irrigation water was slightly decreased soil pH. O.M % decreased with increasing soil depth and the effect of irrigation water quality on organic matter content was not clear.

Regarding to heavy metals in soils, data in Table (3) showed that, using drainage water for irrigating wheat crop in soil (2) led to increase soil contents of available micronutrients (Fe, Mn and Cu) and heavy metals (Pb, Cd and Ni). While, there were no obvious differences in soil contents of these micronutrients and heavy metals with using Nile water for irrigation (soil 1). The mean values of available Fe, Mn and Cu in soil (2) before planting were 16.70, 10.37 and 4.11 ppm. These values increased to 17.95, 10.47 and 4.61 ppm after wheat harvest, respectively. Meanwhile, Pb, Cd and Ni metals mean values were high by about 6.0, 26.3 and 27.7% after wheat harvest than before planting in the same soil, respectively. These results are in agreement with those obtained by El-Wakeel and El-Mowelhi (1993) and Abo-Hussien and El-Koumey (1997). They found that, the total and available forms of heavy metals increased by using poor quality water.

Table (3): DTPA-extractable heavy metals in soils before wheat planting and after harvest.

Treatments	Profile	DTPA-extractable heavy metals, ppm					
	depth (cm)	Fe	Mn	Cu	Pb	Cd	Ni
	Before planting						
Nile water (soil 1)	0-30	18.04	10.32	3.50	0.68	0.04	1.54
	30-60	16.82	9.38	3.46	0.88	0.04	1.38
	60-90	11.98	8.96	3.44	0.92	0.12	1.30
	90-120	11.36	8.80	2.64	0.96	0.12	1.10
	Mean	14.55	9.37	3.26	0.86	0.08	1.33
Drainage water (soil 2)	0-30	20.40	11.62	4.96	1.24	0.10	1.82
	30-60	15.70	10.54	3.54	1.00	0.10	1.84
	60-90	14.66	10.70	3.48	1.32	0.06	2.32
	90-120	16.06	8.60	4.46	1.08	0.12	1.94
	Mean	16.7	10.37	4.11	1.16	0.095	1.98
	After harvest						
Nile water (soil 1)	0-30	19.40	11.72	3.88	0.88	0.10	1.84
	30-60	15.78	9.72	3.46	0.76	0.06	1.12
	60-90	11.92	7.66	2.90	0.60	0.08	1.04
	90-120	11.24	7.74	3.72	1.12	0.06	1.54
	Mean	14.58	9.21	3.49	0.84	0.075	1.39
Drainage water (soil 2)	0-30	22.96	12.82	6.24	1.32	0.12	2.52
	30-60	20.84	11.40	4.70	1.28	0.12	2.56
	60-90	14.74	9.78	3.96	1.20	0.10	2.66
	90-120	13.26	8.94	3.52	1.12	0.14	2.36
	Mean	17.95	10.74	4.61	1.23	0.12	2.53

3. Aggregation stability of soils:

Data in Table (4) indicated that the values of total water stable aggregates > 0.25 mm (TWSA% > 0.25 mm), mean weight diameter (MWD), optimum size of aggregates (2-0.5 mm) (OSA%), structure coefficient (SC) and aggregation index (AI) of the soil under wheat crop decreased with increasing soil depth and after wheat harvest. This may be due to the low values of soil organic mater (O.M%) and the high values of ESP with depth (Table 2). Koriem *et al.* (1988a) reported that aggregation index and percent of water stable aggregates decreased under wheat crop. Also, data showed that, the reduction of TWSA > 0.25, MWD, OSA%, SC and AI values in the soil irrigated with drainage water (soil 2) before wheat planting and after harvest was high compared to soil irrigated with fresh one (Soil 1). Kandil *et al.* (1995) reported hat deterioration in the aggregate status where the large and intermediate aggregate size break down to form small aggregate < 0.5 mm diameter as sequence MWD and aggregation index had decreased due to use low quality water. Also, Van Uffelen *et al.* (1997) revealed that, the sodicity levels might seriously affect soil structure stability.

Table (4): Aggregation stability of the studied soils under wheat crop as influenced by irrigation with different qualities.

Treatments	Soil	Distribution of WSA % > 0.25 mm				Total WSA % > 0.25 mm	Structure coefficient (S.C.)	Optimum size of aggregate	Mean weight diameter (MWD)	Aggregation index (AI)
		8-2 mm	2.1 mm	1-0.5 mm	0.5-0.25 mm					
	Before planting									
Nile water	0-30	0.05	10.25	46.0	12.75	69.05	2.23	56.25	0.549	0.275
	30-60	0.13	12.50	30.0	14.25	56.88	1.32	42.5	0.473	0.236
Drainage water	0-30	1.28	8.0	32.25	12.25	53.78	1.16	40.25	0.470	0.235
	30-60	0.13	5.0	18.25	11.75	35.13	0.54	23.25	0.262	0 131
	After harvest									
Nile water	0-30	0.18	4.75	28.25	13.50	46.68	0.88	33.0	0.343	0.171
	30-60	0.25	5.75	14.75	12.0	32.75	0.49	20.5	0.254	0.127
Drainage water	0-30	0.09	2.0	21.75	15.0	38.84	0.64	23.75	0.254	0.127
	30-60	0.25	1.75	16.25	9.00	27.25	0.49	18.0	0.232	0.116

4. Wheat growth, yield and heavy metals content:

Data in Table (5) indicated that using drainage water for irrigation (soil 2) significantly reduced growth parameters and yield components of wheat crop compared to those irrigated with Nile water (soil 1). The average number of tillers after 60 days from sowing, number of tillers per plant at harvest and number of spikes per plant in (soil 1) were 8, 6 and 5. These values reduced to 4, 3 and 1 in (soil 2) for the abovementioned growth parameters, respectively. Also, maximum growth dry weight, biological yield, straw and grain yield per plant were lower in (soil 2) than (soil 1) by about 8.64, 23.60, 10.52 and 10.01 gm per plant, respectively. The mean weight of 100 kernels were 3.27 and 2.68 gm. for soil (1) and (2), respectively. The reductions in wheat growth parameters may be attributed to soil salinity and specific ion effects on wheat growth. Maria (1992) found that, application of water salinity of 4000 ppm resulted in significant decrease in number of spikes/plant, spike length number of kernels, mean spike weight of 100 kernels and grain yield/plant of wheat in both seasons. Sobh *et al.* (1997) reported that, grain, straw yield and 1000 grain weight had significantly reduced by increasing water salinity in the clay soil.

Table (5): Effect of different sources of irrigation water on growth and yield components of wheat crop.

Plant No.	No. of tillers after 60 days from sowing	Maximum growth dry weight (gm)	No. of tillers/ plant at harvest	Biologic al yield (gm)	Straw yield (gm)	Number of spikes/ plant	Grain yield/ Plant (gm)	100 kernels weight (gm)
				Nile water				
1	9	14.19	7	31.06	20.08	5	10.98	
2	7	9.70	5	25.21	12.27	4	12.94	
3	7	9.23	7	31.69	18.59	7	13.10	
4	7	8.80	6	31.69	20.40	6	11.29	
5	8	13.71	7	25.52	15.96	6	9.56	
6	8	6.29	6	19.25	10.75	6	8.50	
7	10	11.01	7	29.52	19.38	6	10.14	
8	9	16.89	6	33.13	21.22	5	12.11	
9	6	6.51	5	19.08	12.09	4	6.99	
10	8	17.17	6	54.52	36.08	5	18.44	
Average	8	11.35	6	28	13.62	5	11.27	3.27
				Drainage water				
1	4	2.41	3	3.96	2.96	1	1.00	
2	3	3.20	2	3.65	2.80	1	0.85	
3	5	2.95	3	4.67	3.20	1	1.47	
4	3	2.52	2	3.02	2.20	1	0.82	
5	6	1.85	4	4.85	3.45	2	1.40	
6	4	2.87	3	4.23	2.90	1	1.33	
7	5	1.93	4	5.77	3.82	2	1.95	
8	3	2.68	2	4.82	3.60	1	1.22	
9	4	3.65	3	4.98	3.15	2	1.83	
10	2	3.07	1	3.71	2.96	1	0.75	
Average	4	2.71	3	4.4	3.1	1.3	1.26	2.68

As to heavy metals content, results in Table (6) revealed generally that, the studied heavy metals content; Fe, Mn, Cu, Pb , Cd and Ni mg/kg dry matter increased in the grains and straw of the wheat by using mixed drainage water for irrigation (soil 2) compared to that irrigated with Nile water (soil 1). This may be due to the higher concentrations of such metals in the used drainage water than that of Nile water, (Table 1) and consequently the accumulation of these metals in (soil 2) than (soil 1).

Table (6): Effect of water quality on heavy metals contents of wheat plants (mg/kg dry weight).

Treatments	Plant organ	Heavy metals concentrations (mg/kg) dry weight					
		Fe	Mn	Cu	Pb	Cd	Ni
Nile water	Straw	135.8	57.0	6.8	5.5	0.35	15.5
(soil 1)	Grain	62.8	29.5	0.95	0.77	0.08	0.37
Drainage water	Straw	152.0	71.8	8.0	8.5	0.52	19.8
(soil 2)	Grain	67.8	41.5	2.08	1.95	0.15	11.15

These findings are in agreement with those obtained by Zein *et al.* (2002) who reported that, the concentrations of heavy metals in grains and straw of wheat under soil irrigated with drainage water is higher than that irrigated with Nile water. They found also that the concentration of heavy metals in straw of wheat was higher than that in the grains, with both irrigated treatments. The concentration of the previous metals in straw and grains of wheat plants as affected by different sources of irrigation water may depend on many factors such as, total and available concentration of these metals in soil, soil pH and the content of these metals in the irrigation water used, Wolnick *et al.* (1985) and Davis and Smith (1980).

Generally, it could be concluded that, special water and soil management practices (such as mixing with Nile water and/or alternative irrigation with drainage and Nile water, improving soil drainage conditions and addition of some soil amendments such as gypsum and organic matter for soil remediation as well as selection of salt tolerant crop should be followed when farmers obliged to re-use marginal water in irrigation to minimize the hazards effects of such water on soil properties, plant growth, yield quantity and quality as well as human health.

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مخاطر استخدام مياه الصرف لفترة طويلة فى الاراضى الطينية بشمال الدلتا فـــى مصر

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لتقييم مخاطر استخدام مياه الصرف على بعض الخواص الطبيعية والكيميائية للأراضى الطينية وكذلك على نمو محصول القمح ومحتواه من العناصر الثقيلة تـم اختيـار أرض بمركـز سيدى سالم ــ محافظة كفرالشيخ بشمال الدلتا بمصر. الأرض الأولى تروى بمياه النيل مباشـرة بينما تقع الأرض الثانية فى نهاية الترع وتروى عادة بمياه الصرف من مدة حوالى ١٠ سـنوات. وقد تم زراعة القمح صنف سخا ٦١ خلال موسم ٢٠٠٢/٢٠٠٣م بهما.

وقد أظهرت نتائج الدراسة ما يلى:

١- أن استخدام مياه الصرف فى الرى لمدة طويلة أدى إلى زيادة ملوحة وقلوية التربة مقارنـة بالأرض التى تروى بمياه النيل. كما أظهرت النتائج حدوث زيادة بسيطة فى ملوحة وقلويـة التربة بعد حصاد القمح عنها قبل الزراعة فى الأرض الثانية مقارنة بالأرض الأولى.

٢- انخفضت قيم التجمعات الكلية الثابتة فى المياه (WSA) ، ومعامل البنـاء (SC)، ودليـل التحبب (AI) فى الأرض الثانية عن الأرض الأولى قبل الزراعة وكان النقص فى هذه القيم ملحوظا فى الأرض الثانية عن الأرض الأولى بعد حصاد القمح.

٣- احتوت الأرض الثانية على تركيزات مرتفعة من العناصر الثقيلة (Fe ، Mn ، Cu ، Pb ، Cd ، Ni) مقارنة بالأرض الأولى كما زاد محتوى الأرض من هذه العناصر بعد حصـاد القمح فى حين كان التغير فى محتوى الأرض الأولى غير ملحوظ.

٤- اوضحت الدراسة أن إعادة استخدام مياه الصرف فى الرى فـى الأرض الثانيـة أدى إلـى حدوث نقص كبير فى عدد الخلفات ، عدد السنابل ، وزن المادة الجافة عنـد فتـرة النمـو الأعظم ، المحصول البيولوجى للنبات الواحد ، ومحصول القمح من الحبوب والقش مقارنـة بالأرض الأولى.

٥- زاد تركيز العناصر الثقيلة (Fe ، Mn ، Cu ، Pb ، Cd ، Ni) فـى كـل مـن القـش والحبوب لمحصول القمح زيادة ملحوظة بالأرض الثانية مقارنة بالأرض الأولـى ، وكـان تركيزها فى القش أعلى من الحبوب.

٦- أشارت النتائج إلى ضرورة اتباع إدارة جيدة لكل من الأرض والمياه عند اضطرار الفلاحين لاستخدام مياه الصرف فى الرى لمدة طويلة لتقليل مخاطر استخدامها على الأرض والنبـات وصحة الإنسان.