Egypt. J. Soil Sci. **Vol. 42,** No. 4, pp. 705-714 (200_)

Evaluation of Irrigation with Either Raw Municipal Sewage or River Water on Elements Uptake and Yield of Lettuce and Potato Plants

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A FIELD study was performed to evaluate the effect of irrigation water from River Nile or municipal sewage on element concentrations, element uptake their uptake and yield of lettuce and potato plants. The concentration in plants and uptake of elements as well as plant weight were determined at different growth stages of lettuce and potatoes. Concentration and uptake of elements were dependent upon source of water and growth stage. Generally, the concentration and uptake of elements were higher for plant irrigated with municipal sewage water compared to river water. The results of this research reveal that public attention should be concerned with the effect of direct application of municipal sewage as a source for irrigation and organic fertilization especially for vegetables. This source is potentially harmful for the health of animals and humans because it is rich in pathogens and heavy metals.

Keywords: Sewage sludge, Lettuce, Potato, Heavy metal, Nutrients, Irrigation.

The use of raw municipal sewage water in agriculture for the purpose of both irrigation and fertilization has been practiced world wide. Such practice has resulted in an accumulation of heavy metals in soils and plants (McBride, 1995). Plants are the primary entry for heavy metals in food chains. Plant species can differ in their metal uptake and in their effect on rhizosphere and soil heavy metal concentrations (McGrath *et al.*, 1997). The dynamic of heavy metal in the rhizosphere depends on plant species, rate of nutrients uptake, transpiration rate, cation/anion uptake ratio and root cation exchange capacity (Marschner, 1986).

The soluble fraction accounts usually for only 0.5-7.0% of the total amount of sludge born metals (Lake *et al.*, 1984; Liang *et al.*, 1991), but it is a major contribution to the total of metals transported through the soil or taken up by following sludge applications. Metals in the aqueous phase of soil or bio-solids can appear as free ions or as complexes with organic or inorganic ligands. The metal type and environmental conditions such as pH, ionic strength and concentration of potential ligands determine the form of the metal species. Stability constant of transition metal complexes were determined in natural and artificial solutions in the past (Stevenson & Fitch, 1986 and Stevenson & Chen, 1991). Copper, iron, nickel and lead were found to have a strong tendency to form complexes whereas cadmium was a week complex ant. Zinc. cobalt and manganese displayed a moderate tendency to form complexes, and their stability constant values were very much affected by the environmental conditions.

The objective of this studies was to investigate the effect of irrigation with River Nile and sewage water on the bioavailability of heavy metals and their concentration and uptake by lettuce and potatoes grown in the Nile Delta.

Material and Methods

Two sites were selected during 1998/1999 in the east Delta (Qalubia Governarate) to evaluate the effect of two water sources for irrigation (River Nile and raw municipal sewage) on the chemical composition and yield of lettuce and potato plants in each site. The first site was regularly irrigated with raw sewage effluent as a source of water and manure. The second site was irrigated regularly with water of the River Nile and received a recommended dose of N.P.K.

The samples of Nile and wastewater and soils from each site were collected for chemical analysis (Tables 1 and 2).

Plant materials

In both sites, seedlings of lettuce (cv. Balady) were transplanted in mid November 1998. Three plots for every crop were selected in each site. The plot size was 3m in length and 2m width. Each plot contained 4 rows and seedlings were placed 10-15 cm apart. Ten plants from each replicate were taken to determine vegetative growth expressed as number leaves and fresh and dry weight of plant. Chemical analysis at the age of 30, 60 and 90 days from transplanting were conducted.

TABLE 1. Concentrations (ppm) of some elements in River water, aqueous and solid sewage sludge .

Sample	K	Zn	Cu	Fe	Mn	Co	Cd	Pb	Ni
River warer	15.2	0.06	0.04	2	1	-	0.003	0.09	0.06
Waste water.	52.4	1.27	1.04	7.1	3.86	-	0.03	0.35	0.26
Solid sludge	1660	410	150	12000	260	-	12.3	275	43

TABLE 2. Element concentrations (mg/kg^{-1}) in soils of the experimental sites after harveste as affected by treatments.

Depth of	K		Fe		Mn		Zn		Cu		Ni		Cd		Pb		Co	
Sample	R.W	S.W	R.W	S.W	R.W	S.W	R.W	S.W	R.W	S.W	R.W	S.W	R.W	S.W	R.W	S.W	R.W	S.W
0-10	419	488	112	134	80	85.8	2.55	41	23.1	39.3	2.38	6.26	<LLD	0.22	7.88	59.5	1.04	0.8
10-20	345	536	111	134	76	89.1	2.5	41	22.1	36.5	1.89	5.46	0.07	0.11	7.45	60.8	0.97	1.3
20-30	255	492	107	133	57	86.4	2.27	40	20.3	39.1	1.29	5.66	<LLD	0.15	5.69	59.1	0.49	1.3

R.W= River water S.W= Sewage water LLD=Lower limit of detection

In both sites, potato tuber (cv. Diamant) were planted in mid November 1998. Each plot consisted of 4 rows 3.3m long the inter and intra row spacing were 75 and 20 cm, respectively. Vegetative samples were collected from each site to determine plant height, number of main stems, fresh and dry weight of plant and chemical analysis at 45 and 90 days from planting .The experiment was harvested 110 days after planting and the weight of tuber/plant was determined. Soil and plant samples preparation and chemical analysis were conducted according to Coffenie *et al.* (1982).

The obtained data were statistically analysis and means were compared using the L.S.D. methods at 5% level of significance according to Snedecor and Cochran (1980).

Results and Discussion

Table 1 presents an overview of the chemical composition of water from the River Nile, sewage water and solid sludge. It indicates that elements concentrations increased in the following order: River Nile <sewage water <solid sewage sludge. The percentage of soluble fraction of elements in aqueous sewage to that in solid sewage sludge was 3% for K, 0.3% for Zn, 0.7% for Cu,

0.06% for Fe,1.5% for Mn, 0.2% for Cd, 0.1% for Pb and 0.6% for Ni. These results coincide with results obtained by Lake *et al.* (1984) and Liang *et al.* (1991), who found that the soluble fraction accounts usually for only 0.5-7% of the total amount of sludge born heavy metals. However, the ton of row liquid municipal, sewage contain 85 kg of K, 20kg of Zn, 7.5 kg of Cu, 60kg of Fe, 0.6 kg of Cd, 1.4kg of Pb and 2 kg of Ni.

Data in Table 2 for soil samples show that, there was an increase in the concentrations of the bio-availability for elements in soils irrigated with municipal sewage sludge than that irrigated with water of the River Nile. This elevation resulted in increasing the concentrations of elements in and subsequently on their uptake for both plants. This indicate that, when sewage water is used improperly for irrigation and without responsibility cultivated soils and ground water may be polluted and may cause human endanger infection.

Plant growth and yield

Tables 3, 4 and 5 show the effect of irrigation sources of water on growth characters at different growth stages and yield of lettuce and potato plants. Respecting to lettuce plants, the results in Table 3 show that irrigated lettuce plants with sewage water significantly increased leaf number of lettuce plants (except for the third sampling date, which was not significantly different. The data in the same table also show that irrigated lettuce plants with the River water significantly increased both fresh and dry weight of leaves compared to sewage water. This finding was true at stages of 30 and 60 days after transplanting whereas, the reverse was true for the third sampling date, *i.e.*, 90 days after transplanting.

TABLE 3. Response of lettuce plant growth to irrigation with water from the River Nile and sewage water.

Characters	S.W	R.W	LSD	S.W	R.W	LSD	S.W	R.W	LSD
	After one month			After two months			After three months		
Number of leaves	9.21	7.56	0.76	26.4	24.2	0.47	49.43	46.41	N.S
Plant fresh weight (gm)	11.94	23.01	1.65	120.97	193.53	7.24	602.28	561.75	6.61
Plant dry weight (gm)	1.47	2.32	0.13	22.36	27.13	0.15	51.36	49.74	1.49

S.W = Sewage water R.W = River Nile water

TABLE 4. Response of potato plant growth to irrigation with water from the River Nile and sewage water.

Characters	S.W	R.W	LSD	S.W	R.W	LSD
	After 45 days			After 90 days		
Plant height (cm)	28.74	24.24	1.27	49.43	46.41	1.25
Number of main stems	1.2	1.1	N.S	3.02	2.67	N.S
Plant fresh weight (gm)	126.51	133.49	N.S	571.87	608.68	13.42
Plant dry weight (gm)	33.2	33.5	N.S	56.8	51.7	0.71

S.W = Sewage water R.W = River Nile water

TABLE 5. Effect of irrigation with water from the River Nile and sewage water on potapo yield and its components.

Characters	Sewage water	River water	LSD
Number of tubers/plant	4.89	5.43	N.S
yield /plant (gm)	515.47	551.22	9.23
yield (kg /m^2)	3.41	3.67	N.S

Tables 4 & 5 show the growth characters, yield and its components of potato plants as affected by irrigation with municipal sewage water and the River Nile water .The results reveal that irrigated potato plants with sewage water significantly increased plant height at stages of 45 and 90 days from planting. Whereas, no significant differences were noticed in the number of main stem. Regarding the effect of both sources of irrigation on fresh and dry weight of plant, obtained results indicated that, at the second stage, *i.e.*, 90 days from planting irrigated potato plants with River water was of the best as for plant fresh weight whereas, the reverse was true for dry weight.

As for yield and its components irrigated potato plants with the River Nile water rose to a significant higher yield per plant than sewage water. However, the same results were obtained concerning number of tuber per plant and yield per m2, but the effect was insignificant (Table 5).

Chemical composition

Data in Tables 6 & 7 represent the concentrations of elements in plants at different growth stages under both irrigation conditions with municipal sewage sludge and water of the River Nile. In case of lettuce, the concentration of P, K, Fe and Pb increased with increasing growth stages, however, Mn, Zn, Ni, Cd and Co decreased with increasing growth stages along/or after two months. In the case of potato, concentrations of elements in tubers are much lower than that in vegetative part especially after 90 days from planting.

TABLE 6. Concentration of some elements at different growth stages of lettuce irrigated with water from the River Nile and sewage water.

Element	Element at different growth stage					
	Sewage water			River water		
	1	2	3	1	2	3
P%	0.44	0.62	0.61	0.42	0.49	0.6
K%	3.74	3.98	4.33	3.12	3.82	4.25
Mn (ppm)	226	130	141	153	124	119
Fe (ppm)	179	413	749	98	123	114
Zn (ppm)	98	89	58	68	59	54
Cu (ppm)	34	57	29	29	34	28
Pb (ppm)	23	33	40	16	16	36
Ni (ppm)	16	21	14	12	18	12
Cd (ppm)	3	4	3	2	3	2
Co (ppm)	10	20	11	8	11	6

1 = After one month 2 = After two months

3 = After three months

Data in Tables 8 & 9 reveal that the amount of elements uptake by lettuce and potato plants due to irrigation with municipal sewage was much higher than that with the River Nile water. The accumulation of elements in edible part of plant was detected, which adversely affect human, and animal health through the food-chain.

Public attention should be concerned with the effect of direct application of municipal sewage as a source of irrigation and for some fields of vegetables.

TABLE 7. Concentration of some elements at different growth stages of potato plant irrigated with water from the River Nile or sewage water.

Element	Element at different growth stage					
	Sewage water			River water		
	1	2	3	1	2	3
P%	0.58	0.63	0.34	0.34	0.6	0.32
K%	3.74	3.56	1.43	2.87	2.38	1.17
Mn (ppm)	150	267	13	132	145	9
Fe (ppm)	451	352	47	208	215	27
Zn (ppm)	61	119	29	54	62	24
Cu (ppm)	33	52	9	28	36	9
Pb (ppm)	40	39	20	33	16	10
Ni (ppm)	14	16	13	13	8	8
Cd (ppm)	3	4	3	3	1	1
Co (ppm)	15	10	3	6	6	3

1 = After 45 days (in shoots) 2 = After 90 days (in shoots)

3 = At harvest stage (in tuber)

TABLE 8. Uptake of some elements / plant at different growth stages of lettuce irrigated with water from the River Nile or sewage water.

Element	Uptake at different growth stage					
	Sewage water			River water		
	1	2	3	1	2	3
P%	0.7	13.9	31	1	13.3	29.8
K%	5.5	89	222	7.2	103.6	211
Mn (ppm)	332	2906	7242	355	3364	5919
Fe (ppm)	263	9234	38469	227	3337	5670
Zn (ppm)	144	1990	2979	160	1601	2686
Cu (ppm)	50	1275	1489	67	922	1400
Pb (ppm)	33	738	3082	37	434	2785
Ni (ppm)	24	470	729	27	491	606
Cd (ppm)	4.4	89	154	4.6	81.4	99.4
Co (ppm)	14	447	565	18	298	298

1 = After one month 2 = After two months

3 = After three months

TABLE 9. Uptake of some elements / plant at different growth stages of potato irrigated with water from the River Nile or sewage water.

Element	Element at different growth stage					
	Sewage water			River water		
	1	2	3	1	2	3
P%	19	35	30	11	31	27
K%	118	202	124	96	123	97
Mn (ppm)	4976	15171	1079	4421	7494	780
Fe (ppm)	14973	20001	3901	6966	11111	3901
Zn (ppm)	2023	6782	2407	1808	3204	2084
Cu (ppm)	1095	2955	747	938	1860	781
Pb (ppm)	1327	2216	1660	1105	827	867
Ni (ppm)	461	909	1079	442	413	693
Cd (ppm)	100	227	250	100	52	86
Co (ppm)	498	568	250	201	310	260

1 = After 45 days (in shoots) 2 = After 90 days (in shoots)

3 = At harvest stage (in tuber)

This source is very harmful for the health of human and animals because it is very rich by pathogenic and heavy metals. Therefore, it is forbidden to use it before treatment for irrigation of crops such as vegetable and fruits.

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(*Received* 5 /2000)

تقييم الرى بكل من مخلفات الصرف الصحى ومياه النهر على امتصاص العناصر ومحصول كل من الخس والبطاطس

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أجريت تجربة حقلية لدراسة تأثير الرى بكل من مياه نهر النيل ومخلفات الصرف الصحى على امتصاص العناصر ومحصول كل من الخس والبطاطس. وقد أظهرت النتائج أن تركيز وامتصاص العناصر تأثر بمرحلة النمو. وبصفة عامة كان تركيز وامتصاص العناصر أعلى مع الرى بمخلفات الصرف الصحى عن الرى بمياه النهر خلال مرحلة النمو الواحدة لكل من المحصولين المذكورين.

زاد تركيز كل من الفسفور والبوتاسيوم والحديد والرصاص فى أوراق الخس ، بينما انخفض تركيز كل من المنجنيز والزنك مع زيادة عمر النبات مع كل من مصدرى الرى . بينما كان لاستخدام

مخلفات الصرف الصحى كمصدر للرى تأثير واضح فى زيادة تركيز العناصر مقارنة بمياه النهر .

زاد تركيز كل من الفوسفور والمنجنيز والحديد والزنك فى البطاطس بينما قل الرصاص فى الأوراق مع زيادة مرحلة النمو ومن جهة أخرى قل تركيز العناصر بالدرنات عن الأوراق خلال مرحلتى النمو .

زاد الوزن الطازج للخس نتيجة للرى بمخلفات الصرف الصحى عن الرى بمياه النهر . بينما قل وزن وعدد الدرنات للنبات بنسبة ٦,٥ و ٩,٩ ٪ نتيجة للرى بمخلفات الصرف الصحى.

ونظراً للخطر الناجم عن استخدام مخلفات الصرف الصحى كمصدر للرى فيجب أن تجرى معاملة لها للتخلص من العناصر الثقيلة والكائنات المرضية المصاحبة لها لما تسببه من تلوث للتربة وتأثيرها الضار بصحة الإنسان والحيوان ولذا يوقف استخدامها لرى محاصيل الخضر والفاكهة قبل معاملتها .