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Productivity of Maize (*Zea mays*) and Sorghum (*Sorghum bicolor L.*) Using Treated Wastewater for Irrigation

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Abstract: This study was conducted to investigate the utilization of treated wastewater in irrigating maize (*Zea mays*), and sorghum (*Sorghum bicolor L.*) compared with River Nile water. The measured parameters were soil properties, minerals contents, transfer factor, plant growth and yield. The treated wastewater was analyzed with reference to international specification for irrigation water**,** and was found to conform to FAO standards for irrigation. The statistical analysis at $P \leq 0.05$ revealed that the highest values of plant growth and yield parameters, plant dry weight, plant fresh weight, 100-seeds weight and concentration levels of Mg, Na, K, and P in stem tissues of both crops were obtained with treated wastewater as compared with River Nile water. On the other hand, maize showed higher response to the utilization of treated wastewater than River Nile water, as compared with sorghum, in all aforementioned parameters. Treated wastewater significantly ($P < 0.05$) increased Ec, pH, OC, N, Na, Ca, Mg, K, Cl, Cu, Zn, Fe, Mn, Pb, Co and P in soil for a short time and sharply with along time. The study showed that there was no significant ($P < 0.05$) difference between water treatments in transferring the elements from soil to plant. The transfer factors registered were in the order of Ca (0.77), Co (0.74), (0.47), K (0.36), Cu (0.34), Zn (0.28), Pb (0.21), Fe (0.16), Mn (0.12) and Na

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(0.11). Hence it can be concluded that treated wastewater can be utilizeded satisfactorily for producing field crops such as maize, sorghum and forage.

Keywords: Treated wastewater, water quality, maize, sorghum

INTRODUCTION

Wastewater means domestic sewage, industrial effluent or combination of the two. It contains hazardous impurities, so that it has to be treated (Pescod, 1992). It refers to the liquid waste discharged from homes, commercial premises and industrial plants to individual disposal systems or municipal sewer pipes (Armitage, 1985). Sewage is an inevitable product of population centers and must be disposed of. The main sources of wastewater are agricultural drainage water, runoff losses from irrigation systems and fields, sewage water from cities, leakage from water supply systems, high percolation and wastewater from treatment plants (Hussian and Alsaati, 1999).

The treatment and reuse of the wastewater can remove a potential cause of environment, ground and surface water pollution and at the same time can help in solving the expected water scarcity (Eltoum, 2002). Municipal wastewater is one of the most readily available alternative water sources for mitigating the damage of the present natural resources (Pollice *et al.*, 2004). Treated effluent contains plant nutrients and has a potential value as fertilizer (Martens and Westermann, 1991). Nutrients in municipal wastewater and treated effluents are particular advantages of these sources over conventional irrigation water resources (Pescod, 1992). On the other hand, municipal wastewater effluent may contain a number of toxic elements including heavy metals, because under practical conditions wastes from many small and informal industrial sites are directly discharged into the common sewer system (Pescod, 1992).

Reclaiming municipal wastewater for agriculture use is increasingly recognized as an essential management strategy in areas of the world where water is in short supply (Khouri *et al.*, 1994). Irrigation with wastewater would permit a more efficient use of water resources and considerably limit environmental damage due to the direct introduction into surface bodies (World Commission on Environmental Development "WCED", 1987). Reuse of wastewater, can improve the physical properties and agricultural productivity of soils, and its agricultural use provides an alternative to disposal options, such as incineration and land fill (Martens and Westermann, 1991). Land application of wastewater can help to remedy the trace elements deficiencies in soil. But the longtime use and poor practices of wastewater application to soil lead to some negative effects on soils and crops (Cajuste *et al.*, 1991).

Maize and sorghum are essential cereal crops for both human and animals, which represent the main source of carbohydrates, cheaper source for calories, and main component of animal forage, and can be used as green forage and can be used in fuel production in form of biogas and ethanol, (Ishag, 2004). Treated wastewater can be used to produce maize and sorghum crops with acceptable quality.

In big towns and sectors substantial quantities of wastewater are usually dumped to waste around the town which may cause very serious pollution hazards. This problem increases day by day due to the increase of population and industrial sector in such towns. This study is concerned with seeking the potentialities of reusing treated wastewater in irrigation for producing maize and sorghum crops under Khartoum state conditions. Moreover, its effect on soil properties was evaluated.

MATERIALS AND METHODS

The experiment was conducted in the Demonstration Farm of the Faculty of Agriculture**,** University of Khartoum (15.40° , 32.32° E and 380 m above sea level), during 2011. Soil samples were collected from experimental site as well as from Yarmouk Military Farm**,** south of Khartoum, to check the effect of using treated wastewater on soil for extended period.

Material

1. A 5000 gallon tanker was used for transferring treated wastewater from Soba treatment plant.
2. An auger of 10 cm size was used for soil sampling
3. A measuring tape was used for measuring plant height.

4. A vernia was used for measuring plant stem size.
5. Sensitive balance
6. Laboratory equipment for soil and water analyses

Methods

Composite water samples were taken from the effluent at the final treatment point from three locations at Soba sewage treatment plant. The bottles used were cleaned with hot water and suitable detergent**,** rinsed with hot water to remove all traces of detergent used and finally were sterilized in an autoclave. The samples of treated wastewater were chemically analyzed for bicarbonate (HCO_3)**,** chlorides (Cl)**,** Sodium (Na), Boron (B), Nitrate (NO_3-N)**,** Phosphate PO_4**,** Hardness, Heavy Metals in mg/l, pH**,** Electrical Conductivity (EC) dS/m, Sodium Adsorption Ratio (SAR)**,** and Total Coliforms Tc/100.

Soil samples at 0-80cm were augured before and after each treatment**,** to represent the effective root zone depth. The parameters measured were soil texture**,** pH**,** EC**,** Nitrogen (N %), Total Phosphorus (TP%)**,**Organic Carbon (OC %) and trace elements. Similar analyses were made for the samples taken from two sites at Yarmouk Farm in which one was under irrigation with treated wastewater for several years and the second site never received treated wastewater at all.

The plant parameters measured were plant height, stem size, numbers of leaves per plant, leaf area index, weight of ten plants taken at random from each plot, 100-seeds weight (g.) and crop yield (kg/ha).

The concentration of nutrients in plant tissues was measured in the plant extract as obtained from fresh plant material as well as from a whole dried plant material**.** The parameters measured were: Crude Protein (N %)**,**Total Phosphorus (TP %) and Mineral content (mg/l)**.**

The transfer factor was determined as suggested by Izosmova *et al.*(2005) in the following relation:

$$TF=\frac{\text{element concentration in plant mg/kg}}{\text{element concentration in soil mg/kg}}$$

The experiment was organized in Complete Randomized Design (CRD) where short furrow irrigation was practiced. The package of SAS under windows was used to achieve the analysis.

RESULTS AND DISCUSSION

The quality of treated wastewater

Table 1. Shows the chemical analysis of the treated wastewater with reference to FAO standards**.** The analysis showed that the concentration of most of the parameters lie within slight to moderate levels**.** However, concentration higher than the maximum permissible levels were recorded for HCO_3**,** Co and Cu**.** The appearance of the previous mentioned elements in high concentration may be due to the source of this water, which was delivered from municipal, commercial complex and industrial sector. Pescode (1992) stated that the concentration of wastewater constituents depends upon the water supply, and degree of treatment. Hence it can be stated that Khartoum State treated wastewater can be accepted as suitable irrigation water according to FAO standards but under strict supervision particularly when used under sprinkler irrigation system due to the high level of bicarbonates which can lead to continuous problems of white formation on leaves and fruits as reported by Ayers and Wescot (1989)**.**

Transfer Factor of elements between Soil and Plant

Table 2. Shows that there were no big differences between water treatments in transferring the elements from soil to plant. However, Ca and Co were transferred relatively in high rates followed by P, K, Cu, Zn Pb, Fe, Mn and Na, respectively. In general transfer factor was highly dependent on the concentrations of elements in the soil, soil type and pH. This confirmed by the finding of Guo *et al.* (1995) and Zufiaurre *et al.* (1998).

Long term (ten years) effects of using treated wastewater in irrigation on soil chemical properties at Yarmouk Farm

Table 3.shows the comparison made between two soil samples ($S_1$and S_2) taken from Yarmok site, in which one was irrigated by treated wastewater for a long period and the other where no application of treated wastewater was made. The results showed that the application of treated wastewater

for a long time increased pH, EC, N, OC, K, Na, Ca, Mg, Cl, Cu, Mn, Fe, Zn and Pb in the soil. Results also revealed that Na and Cl concentrations increased sharply while no difference was found between both soils in phosphorus (P). This may be due to the fact that treated wastewater has high contents of trace elements and heavy metals as well as nutrients. This agreed with the findings of EPA (1996), Mendoza *et al.* (1996), Filip *et al.* (1999), Hayat *et al.* (2002), Ramirz *et al.*, (2002) and Abdelsabour (2003).

Table 1. Treated Wastewater compared with FAO Standards for irrigation water

Potential Irritation Problem	**Units**	**FAO*** Degree of restriction on use: **none**	**Slight to Moderate**	**Severe**	**TW****
Ec_w	dS/m	<0.7	0.7 – 3.0	>3.0	0.9
SAR When Ec_w in range of (0-3)		>0.7.	0.7- 0.2	<0.2	0.5
Sodium	me/l	< 3	3-9	>9	0.5
Chloride (Cl)	me/l	<4	4-10	>10	7
Bicarbonate (HCO_3)	me/l	<1.5	1.5-8.5	>8.5	9.5
Nitrogen (NO_3-N)[3]	me/l	<5	5-30	>30	0. 3
Boron (B)	me/l	<0.7	0.7 – 3.0	>3.	-
Calcium	mg/l	MRC 42			41.73
Magnesium	mg/l	MRC 20			19.5
Copper	mg/l	MRC 0.2			0.4
Cobalt	mg/l	MRC 0.05			0.1
Chromium	mg/l	MRC 0.1			0.03
Zinc	mg/l	MRC 2			0.3
Lead	mg/l	MRC 0.1			0.05
Iron	mg/l	MRC 5			0.3
E coli***	cfu/100 ml	MRC 126			61
pH	**Normal range 6.5 – 8.4**				**8.1**

* FAO standard is taken as an international standard

** TW: the Treated Wastewater used in the study

MRC: Max Recommended Concentration

Table 2. Transfer Factor (TF) of elements between soil and sorghum for the irrigation treatments

The elements	**Water treatment**	
	Treated Wastewater	River Nile Water
Na	0.11	0.11
Ca	0. 77	0.58
K	0.36	0.39
Fe	0.16	0.19
Cu	0.34	0.30
Mn	0.12	0.15
Zn	0. 28	0. 26
Pb	0. 21	0. 10
Co	0.74	0.62
P	0.47	0.43

Table 3. Long term effect of irrigation by treated wastewater on soil chemical properties at Yarmouk Farm

Measured parameters	**Soil treatment**	
	S_1*	S_2**
pH	8. 6	9. 13
Ec*dS/m*	2. 87	4. 46
N *mg/l*	3.0	8.0
OC *%*	0. 37	0. 55
P *%*	0. 10	0. 10
K *me/l*	0. 28	0. 513
Na *me/l*	65. 89	135. 86
Ca*me/l*	12.0	12. 5
Mg *me/l*	6. 5	8.0
Cl*me/l*	69. 85	115. 98
Fe *mg/l*	1. 22	1. 37
Cu *mg/l*	0. 70	0. 72
Zn *mg/l*	0. 28	0. 74
Mn*mg/l*	0. 5	0. 79
Pb*mg/l*	0. 42	0. 48

*S_1soil which has not been subjected to irrigation by treated wastewater.
**S_2soil which has been subjected to irrigation by treated wastewater for ten years

Effect of treated wastewater on Plant Growth Parameters and Yield Kg/ha as compared with River Nile water

Plant height, stem size, number of leaves per plant, leaf area index, plant fresh and dry weight, 100-seeds weight, and yield Kg/ha were studied and the comparison between the water treatments was made (Tables 4 and 5). Treated wastewater revealed significant differences ($P \leq 0.05$) in increasing the magnitudes of the aforementioned parameters of sorghum and maize as compared with the effect of River Nile water. These results can be attributed to the fact that treated wastewater is enriched in macro and micro nutrients, a fact in agreement with the findings of FAO (1985), Martens and Waterman (1991), Pescod (1992) and Widaa and Saeed (2008). It also agrees with the finding of Fasiolo *et al.* (2002), which stated that using treated wastewater to irrigate crops increased crops production by 30- 40%. On the other hand comparison between the two crops showed that maize significantly had higher values than sorghum. This may be attributed to the fact that maize uptakes the nutrients in a rate more than than that of sorghum. This finding agrees with the findings of Ramirez *el al.* (2002).

The concenetration of Ca, Mg, Na , K, N and P in stem tissues

As shown in table (6), the concentrations of Na, Mg, K, and P in the stem tissues of the both crops are significantly ($P \leq 0.05$) increased with treated wastewater in comparison with River Nile water, while there are no significant differences in concentrations of Ca, N. While table (7) shows the effect of crop types on concentration of the forementioned elements in stem tissues. Whereas The comparison between the two crops showed that the concentration of Ca, Mg, K and P significantly ($P \leq 0.05$) increased with maize, while there are no significant differences recorded in the concentration of Na and N. These results agree with the finding of Hussian and Elsaati (1999).

Table 4 Effect of treated wastewater on Plant Growth Parameters and Yield of Maize as compared with River Nile water

Water types	Plant Growth Parameters and Yield of Maize							
	Plant height (cm)	stem size (cm)	number of leaves per plant	leaf area index (cm^2)	Plant fresh weight (g)	dry weight (g)	100-seeds weight (g)	yield Kg/ha
Treated wastewater	148[a]	3.9[a]	13[a]	5.9[a]	477[a]	142[a]	25[a]	5862[a]
River Nile Water	138[b]	1.3[b]	6[b]	2.5[b]	232[b]	119[b]	16[b]	4182[b]
LSD	6.4	0.12	0.4	0.41	30	5	2	69

Means in column which are followed by similar letters are not significantly difference at 0.05 level of probability.

Table 5 Effect of treated wastewater on Plant Growth Parameters and Yield of Sorghum as compared with River Nile water

Water types	Plant Growth Parameters and Yield of Sorghum							
	Plant height (cm)	stem size (cm)	number of leaves per plant	leaf area index (cm^2)	Plant fresh weight (g)	dry weight (g)	100-seeds weight (g)	yield Kg/ha
Treated wastewater	99[a]	3.8[a]	13[a]	5.2[a]	460[a]	89[a]	9.4[a]	5062[a]
River Nile Water	76[b]	1.6[b]	6[b]	2.6[b]	222[b]	57[b]	3.5[b]	3934[b]
LSD	6	0.12	0.4	0.4	31	4.8	1.6	68

Means in column which are followed by similar letters are not significantly difference at 0.05 level of probability.

Table 6. Effect of water types on concentration of some elements inthe crops tissues

Types of Water	Ca	Mg	Na	K	N	P
Treated Wastewater	1.000[a]	0.198[a]	0.676[a]	2.017[a]	2.287[a]	0.082[a]
River Nile	0.946[a]	0.158[b]	0.319[b]	1.690[b]	1.959[a]	0.058[b]
LSD	0.260	0.054	0.021	0.760	0.757	0.131

Means in column which are followed by similar letters are not significantly difference at 0.05 level of probability.

Table 7. Effect of crop types on concentration of some elements in the tissues

Treatment	Ca	Mg	Na	K	N	P
Maize	1.103[a]	0.205[a]	0.508[a]	2.233[a]	2.402[a]	0.079[a]
Sorghum	0.843[b]	0.151[b]	0.487[a]	1.473[b]	1.844[a]	0.061[b]
LSD	0.053	0.040	0.326	0.326	0.327	0.128

Means in column which are followed by similar letters are not significantly difference at 0.05 level of probability.

CONCLUSIONS

With reference to FAO standard, wastewater as treated in Soba treatment plant can be used for irrigation purposes of field crops. Therefore, Wastewater should be viewed as a resource which must be recovered and added to the water budget. Soil chemical properties are highly affected by using treated wastewater in irrigation of crops. On the other hand, both crops showed inordinate response to treated wastewater, which reflected in higher yield compared with River Nile water. Further research is needed to enrich the knowledge in this important field.

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إنتاجية الذرة (*Zea mays*) و الذرة الرفيعة (*Sorghum bicolor L.*) عند استخدام المياه العادمة المعالجة في الري

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مستخلص البحث: أجريت هذه الدراسة لبحثالاستفادة من مياه الصرف الصحي المعالجة في ري الذرة (*Zea mays*) ، والذرة الرفيعة (*Sorghum bicolor* L.)، مقارنة بمياه نهر النيل. كانت المعاملات المقاسة هي خصائص التربة ، المحتوي من المعادن ، عامل النقل، نمو النبات و الإنتاج. تم تحليل المياه العادمة المعالجة بالرجوع إلى المواصفات الدولية لمياه الري ، ووجد أنها تتفق مع معايير منظمة الأغذية والزراعة للري. أظهر التحليل الإحصائي($P\leq 0.05$)أن أعلى قيم لنمو النبات وعوامل الإنتاج ، والوزن الجاف للنبات ، والوزن الرطب للنبات، ووزن 100 بذرة ومستويات تركيز المغنيسيوم، الصوديوم، البوتاسيوم، والفسفور في أنسجة الساق لكلا المحصولين مع مياه الصرف المعالجة مقارنة بمياه نهر النيل. من ناحية أخرى، أظهرت الذرة استجابة أعلى لاستخدام مياه الصرف المعالجة من مياه نهر النيل، مقارنة بالذرة الرفيعة، في جميع المعايير المذكورة أعلاه. أظهر استخدام المياه العادمة المعالجة في زيادة معنوية ($P<0.05$) لكلا من:Ec،pH OC، N، Na، Ca، Mg، K، Cl، Cu، Zn، Fe، Mn، Pb، Co و P في التربة في حالة استخدامه الفترة زمنية قصيرة وبشكل أكبر في حالة الاستخدام لفترة زمنية طويلة. كما أظهرت الدراسة أنه لا يوجد فرق معنوي ($P<0.05$) بين معاملات المياه في نقل العناصر من التربة إلى النبات. كانت عوامل النقل المسجلة في حدود Ca (0.77) و Co (0.74) و (0.47) K (0.36) و Cu (0.34) و Zn (0.28) و Pb (0.21) وFe (0.16) و Mn (0.12) و Na (0.11). ومن هنا يمكن الاستنتاج أن مياه الصرف الصحي المعالجة يمكن استخدامها بصورة مقبولة لإنتاج المحاصيل الحقلية مثل الذرة والذرةالرفيعة.

الكلمات المفتاحية: مياه الصرف المعالجة ، جودة المياه ، الذرة ، الذرة الرفيعة

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