Agriculture College – Wasit University

Dijlah Journal of Agricultural Sciences

ISSN 2790 – 5985
eISSN 2790 – 5993

Dijlah J. Agric. Sci.، 4(2):52-62, 2025

The effect of irrigation with wastewater on soil chemical properties and availability of macronutrients (NPK)

Hafsa Muhammad Hamza Al-Ajili1 Kahraman Hussein Habeeb 2, Kadhim Makke Naser3

[1,2,3] Department of Soil and Water Resources, College of Agriculture, University of Wasit, Wasit, Iraq

College of Agricultural Engineering Sciences - University of Baghdad

Corresponding author: ban@uowasit.edu.iq

Abstract:

In order to know the effect of irrigation with wastewater on some chemical properties of soil and availability of macronutrients NPK, a pot experiment was conducted in one of fields affiliated with Karbala Governorate sewage station using soil with a silty loam texture. A completely randomized design (CRD) was used with two types of irrigation water (wastewater and tap water) and six replicates. Zeya maize seeds of Sumer variety were planted on 1/9/2024. Experiment continued until the male inflorescences appeared on 3/12/2024. Plant and soil samples were taken after the experiment ended. Results showed the following: Soil reaction, electrical conductivity, organic matter, cation exchange capacity, and Sodium adsorption rate increased in soil irrigated with wastewater compared to soil irrigated with tap water. They were 6.80, 7.58 dS m-1, 18.13 g kg-1, 13.15 C.mol kg-1, and 1.286 (mmol L-1) ½, respectively. Concentrations of Nitrogen, Phosphorus, and Potassium in soil increased as a result of irrigation with wastewater, reaching 10.70, 22.10, and 98.00 mg kg-1, respectively.

Keywords: Irrigation with Wastewater, Chemical and fertility properties of soil, Zeya maize.

Received:22/4/2025 **Accepted:27/5/2025** **Published:30/7/2025**

Introduction

Freshwater is the most important water for various human activities, including drinking and irrigation, as well as other ecosystem processes (Hassan et al., 2018). Increase in world's population, high population density in urban areas and major cities, increased demand for food and increased pressure on regional water resources, it led to the use of sewage water to irrigate agricultural lands. Al-Mayah, Rabee, (2018) and Al-Ani et al. (2019) showed that Tigris River water is polluted with varying levels of pollutants due to the dumping of various wastewater into it. Wastewater is a non-traditional water resource that contributes to increasing green spaces and creating green belts around cities to combat desertification. It can also be used to irrigate suitable agricultural plants in safe ways that do not affect human health and preserve the environment. Sewage is liquid waste or water whose quality has changed negatively as a result of various human uses. It includes liquid waste discharged from residential, industrial, commercial and agricultural complexes.

It may also contain many potential pollutants at varying concentrations. If the concentration of toxic elements is higher than permissible limits, water is considered polluted and dangerous to human, plant, and animal life (Al-Obaidy et al., 2014). Using wastewater for irrigation increases soil fertility due to organic matter and nutrients it contains and reduces pressure on fresh water consumption. Abbas et al. (2018) and Al-Saadoun et al. (2024) showed that are temporal and spatial changes in physical and chemical factors of river water depending on percentage of pollutants in it. Khan et al., 2009. showed that content of soils irrigated with wastewater was high in major elements, Nitrogen, Phosphorus, Potassium, Calcium and organic matter. The improper use of wastewater in irrigation leads to harmful environmental effects on soil, agricultural crops, groundwater, public health and the environment in general, given that this water contains substances that may be toxic to humans, plants and animals, including heavy metals, organic and inorganic materials, especially when present in high concentrations, They accumulate in soil and are transmitted through the food chain to plants, animals, and then humans, causing serious diseases. They also lead to significant changes in physicochemical properties of soil (Salman and AlShammary, 2020). Warraq and Salah (2013) explained that soil irrigated with sewage water in Port Sudan city is polluted with heavy metals, and percentage of cations and ana ions in soil is high. It also causes air pollution with toxic gases such as hydrogen sulfide H_2S and ammonia NH_3 that are emitted from liquid waste, which indicates that it is an unsuitable soil for plants. Al-Mansouri et al. (2016) showed that soil salinity increased by approximately three times and the sodium adsorption rate increased by about ten times when wastewater was used to irrigate soil. Meanwhile, the percentage of organic matter increased slightly, Nitrogen, Phosphorus, and Potassium. Therefore, research aims to determine effect of irrigation with wastewater on chemical properties of soil and availability of macronutrients (NPK).

Materials and Methods

Wastewater samples were collected before entering wastewater treatment plant in Karbala Governorate, and after completion of treatment process and before being discharged into river on July 15/7/ 2024. These samples were collected using clean, 2-liter polyethylene containers that were pre-washed with dilute hydrochloric acid (10%) in three replicates, then rinsed with distilled water. Samples were stored in a refrigerator until physical and chemical analyses were conducted, according to methods described in Standard Methods (1995). A pot experiment was conducted in one of fields of Karbala Unified Sewage Station. A soil sample was taken from Al-Hussainiya area of Holy Karbala Governorate at a depth of 0-30 cm. Soil was air-dried and passed through a sieve with a diameter of 4 mm holes. It filled into plastic pots at a rate of 20 kg of soil per pot and compacted several times to obtain an apparent density close to that of field soil. Some chemical and physical properties were estimated according to methods mentioned in Page *et al*. (1982), Jackson (1958), and Black *et al*. (1965) (Table 1). A completely randomized design (CRD) was used with two types of irrigation water (sewage and tap water) and six replicates, so the number of experimental units was: 2 (water type) x 6 (replications) = 12 experimental units. Zeya maize seeds of Sumer variety were planted on 9/1/2024, at a rate of 5 seeds per pot. After 15 days of planting, plants were thinned to three per pot after Zeya maize plant reached male inflorescence stage on 12/3/2024 (end of experiment), Irrigation was carried out with two types of irrigation water after draining 50% of available water as calculated by gravimetric method, and moisture content was maintained throughout growing season. Soil samples were taken after end of experiment, chemical properties and concentration of available NPK macronutrients were estimated according to methods given in Page *et al*. (1982), Jackson 1958, and Black *et al*. (1965) (Table 1).

Table 1. Selected chemical and physical properties of the soil before planting.

Property	**Unit**	**Value**
Chemical properties		
EC	dS m^{-1}	2.15
pH	—	7.06
Organic matter	g kg^{-1}	3.90
CEC	cmol(+) kg^{-1}	11.36
Carbonate minerals	g kg^{-1}	268.00
SAR	$(mmol\ L^{-1})^{0.5}$	0.98
Soluble ions		
Ca^{2+}	meq L^{-1}	10.50
Mg^{2+}	meq L^{-1}	6.11
Na^{+}	meq L^{-1}	3.99
K^{+}	meq L^{-1}	0.75
SO_4^{2-}	meq L^{-1}	1.95
Cl^{-}	meq L^{-1}	17.53
HCO_3^{-}	meq L^{-1}	0.70
CO_3^{2-}	meq L^{-1}	Nil
Available macronutrients		
N	mg kg^{-1}	5.12
P	mg kg^{-1}	6.00
K	mg kg^{-1}	81.85
Physical properties		
Sand	g kg^{-1}	532
Silt	g kg^{-1}	398
Clay	g kg^{-1}	70
Soil texture class	—	Sandy loam
Bulk density	Mg m^{-3}	1.25
Available water	$cm^3\ cm^{-3}$	0.220

A completely randomized design (CRD) was used. Zeya maize seeds of Sumer variety were planted on 1/9/2024, until the yellow corn plant reached the male inflorescence stage on 3/12/2024 (end of experiment). Irrigation was carried out with two types of irrigation water after draining 50% of available water as calculated by gravimetric method, moisture content was maintained throughout the growing season. Plant and soil samples were taken after the end of experiment.

Table 2. Some physical, chemical and biological properties of water.

characters	Unit	treated wastewater	untreated sewage
EC	dSm^{-1}	1.20	8.50
pH	------------	7.59	7.48
TDS	$mg\ L^{-1}$	775.00	5150.00
TSS		10.00	99.00
BOD		0.90	140.00
COD		10.00	236.00
OIL & Grease		0.00	10.10
Total Hardness		3.47	66.50
Turbidity	NTU	0.90	200.00
Ca^{+2}	mmole L^{-1}	2.81	14.97
Mg^{+2}		1.90	10.29
Na^{+}		1.23	24.16
K^{+}		0.29	8.23
NH_4^{+}		0.81	2.50
SO_4^{-2}		1.73	13.97
NO_3^{-}		10.00	8.29
PO_4^{-3}		10.07	8.10
Cl^{-}		30.28	24.23
Sodium adsorption (ratio SAR)	$(mmole+\ L^{-1})^{½}$	0.804	6.805
Water class (USDA,1954)		C_3S_1	C_4S_1

Results and Discussion

1- Soil reaction (pH)

Results of Table 3 show that there are no significant differences in degree of soil reaction irrigated with two different types of irrigation water, but all values tend towards basicity. Value of soil reaction increased in soil irrigated with wastewater relative to its value in soil before planting (7.06-7.58). This may be due to presence of algae and phytoplankton in wastewater, which contribute to conversion of bicarbonate ions into carbonate ions and carbon dioxide gas. The process of consuming CO_2 gas leads to an increase in pH of water, which is reflected in soil irrigated with it. An increase in degree of soil reaction is observed in soil irrigated with tap water, reaching 7.60. High soil reaction values in this soil may be due to almost inverse relationship between soil salinity and degree of its reaction. These results are

Table 3. Some chemical properties of soil irrigated with different types of irrigation water after cultivation.

		Value	

Characters	Unite	soil irrigated with wastewater	Soil irrigated with tap water	LSD 0.05
EC	dSm^{-1}	6.80	2.50	1.497*
pH	-----------	7. 58	7. 60	NS
O.M	gm kg^{-1}	18.13	4.60	1.961*
CEC	Cmole+kg^{-1}	13.15	11.37	1.536*
Carbonate minerals	gm kg^{-1}	200.00	264.00	10.851*
SAR	$(mmole+ l^{-1})^{0.5}$	1.286	1.017	0.216*

consistent with what Al-Yasiri (2007) and Malitan *et al*. (2019) reached, who explained increase in soil reaction values as a result of irrigation with untreated wastewater and its tendency towards slight alkalinity.

2-Soil salinity

Results of chemical and statistical analysis of soil irrigated with different types of irrigation water (Table 3) show an increase in electrical conductivity (EC) (which expresses the amount of ions dissolved in soil solution and is a function of soil salinity) for soil irrigated with wastewater, it was significantly higher than soil irrigated with tap water, reaching 6.80 and 2.50 dS^{-1}, respectively. Electrical conductivity value of soil irrigated with untreated wastewater increased (from 2.15 dS^{-1} before planting to 6.80 dS^{-1} after planting, Table 3). It may be due to increase in amount of pollutants released into it and consequently increase in concentration of salts in it (Table 4) (Hashim, 2017, Al-Saidi and Al-Aboudi, 2010, Al-Obaidy *et.al*, 2014,Alsaadoon, *et al*, 2024) .This is noted from results of Table 1, which indicates an increase in concentrations of cataions and anaions in wastewater compared to tap water, which is reflected in salinity of soil as a result of irrigation. These results are consistent with what was indicated by Militan *et al*. (2019), Milad *et al*. (2019), and Al-Mashri (2022), who showed an increase in concentrations of dissolved ions and thus an increase in electrical conductivity values of soil irrigated with wastewater. Increasing electrical conductivity of soil is one of harmful effects that harms the health, properties and productivity of soil and transforms it over time into saline soil that is unsuitable for agriculture.

Table 4. Concentration of dissolved ions in soil irrigated with different types of irrigation water after planting.

Characters	Unite	Value		LSD 0.05
		soil irrigated with wastewater	Soil irrigated with tap water	
Dissolved aions				

Ca^{+2}	meq L^{-1}	34.28	12.20	1.163*
Mg^{+2}		22.59	8.30	1.301*
Na^{+}		9.70	4.60	1.280*
K^{+}		1.21	0.80	0.252*
SO_4^{-2}		11.24	3.19	1.540*
Cl^{-}		54.30	20.25	3.114*
HCO_3^{-}		2.54	0.70	0.316*
CO_3^{2-}		Nill	Nill	1.163*

3-Organic matter

Results of chemical and statistical analysis of soil in Table 3 show significant differences in amount of organic matter in soil as a result of irrigation with different water types. Soil treated with wastewater outperformed soil irrigated with tap water in amount of organic matter, reaching 18.13 and 4.66 g kg^{-1}, respectively. Increase in amount of organic matter in soil irrigated with wastewater (from 3.90 g kg^{-1} before planting (Table 1) to 18.13 g kg^{-1} after planting) may be due to different organic materials present in this water (Garcia-Orenes *et al*., 2015; Harmoush *et al*., 2013). These results are consistent with the findings of Palese *et al*. (2006) and Milad *et al.* (2019), who demonstrated that increase in organic matter in soil irrigated with wastewater is due to presence of a significant amount of organic matter in this water.

4- Cation exchange capacity (CEC)

Results of Table 3 indicated significant differences in value of cation exchange capacity (CEC)((which expresses the amount of ions exchanged on exchange complex in soil and is a function of soil fertility) of soil irrigated with different types of irrigation water. Soil irrigated with sewage water was significantly superior to soil irrigated with tap water, as values reached 13.15 and 11.37 C. moles of charge kg^{-1}, respectively. CEC value of soil increased from 11.36 before planting to 13.15 C. moles of charge kg^{-1} after planting. Increase in CEC value of soil irrigated with wastewater may be due to organic materials added to soil, which come from wastewater, as organic matter is one of most important factors affecting value of exchange capacity of cataions in soil because it contains active groups such as NH_2^-, $COOH^-$ and OH^-, which ionise to remove negative charge in soil, in addition to presence of humic acids such as humic and fulvic acids in organic matter when it decomposes, which have a high ability to bind and hold heavy metals by forming chelating compounds with different structural and chemical specifications (Al-Tamimi, 1996). Value of (CEC) was not affected in soil irrigated with tap water.

5- Sodium adsorption ratio (SAR)

Results of chemical analysis and statistical of soil after planting (Table 3) showed that Sodium adsorption ratio value ,(which expresses the concentration of exchangeable sodium ions relative to exchangeable calcium and magnesium ions, and is a measure of availability of sodium in soil solution) of soil irrigated with sewage water was significantly higher than that of soil irrigated with tap water, as values reached 1.286 and 1.017 (mmol charge L^{-1}) ½ respectively. Thus, Sodium adsorption ratio value in soil irrigated with sewage water increased from 0.980 (mmol charge L^{-1}) ½ in soil before planting (Table 1) to 1.286 (mmol charge L^{-1}) ½, and this may be due to high value of electrical conductivity of soil due to high concentrations of Ca, Mg and Na ions in untreated wastewater that accumulated in soil, and this is consistent with what was indicated by Al-Mansouri *et al*. (2016)and Abdul Karim and Mahni (2021) who showed an increase in value of Sodium adsorption ratio in soil irrigated with treated wastewater, they also pointed out that continued irrigation with untreated wastewater will lead to an increase in exchangeable Sodium ions in soil, which may affect the growth of Sodium-sensitive plants and also affect ionic balance of soil solution.

6- Available macronutrients NPK

6-1 Nitrogen

Results of chemical and statistical analysis in Table 5 show differences in concentration of available Nitrogen in soil irrigated with different irrigation waters after planting. Concentration of Nitrogen in soil irrigated with wastewater increased from 5.12 mg kg^{-1} before planting to 10.70 mg kg^{-1} after planting, while in soil irrigated with tap water it reached 6.13 mg kg^{-1} soil after planting. High Nitrogen concentration in soil irrigated with wastewater may be due to organic matter present in wastewater, which, when decomposed, increases Nitrogen concentration, in addition to high Nitrogen concentration in untreated wastewater, which reached 2.50 for Ammonium and 8.29 mmol L^{-1} for Nitrate (Table 2). Also, water coming from agricultural lands that use nitrogenous fertilizers with drainage water and which is discharged with sewage water has a major role in increasing concentration of Nitrogen in sewage water, which in turn is transferred to soil when irrigated with it (Muhammad and Rajab, 2017).

6-2- Phosphorus

Results of chemical and statistical analysis in Table 5 show a significant increase in concentration of available phosphorus in soil irrigated with wastewater compared to soil irrigated with tap water, with concentrations reaching 22.10 and 8.90 mg kg-1 soil, respectively. Phosphorus concentration in soil irrigated with wastewater after planting increased from 6.00 mg kg^{-1} before planting to 22.10 mg kg^{-1}, an increase of 72.85%, this may be due to the Phosphate fertilizers that are added to agricultural soil and that are transferred with drainage water to sewage networks, in addition to water that comes from factory waste that contains Phosphorus, such as factories that produce detergents such as shampoo, soap, etc. These results are consistent with what Muhammad and Rajab (2017) showed about increase in concentration of Phosphorus in sewage water, which leads to an increase in concentration of Phosphorus in soil when irrigated with it.

Table 5. Concentration of major nutrients (NPK) in soil irrigated with different irrigation water types after planting.

Characters	Unite	Value		LSD 0.05
		soil irrigated with wastewater	Soil irrigated with tap water	
Available macronutraiants				
P	mg kg^{-1}	22.10	8.90	1.970*
N		10.70	6.13	1.503*
K		98.00	70.00	7.450*

6-3- Potassium

Results of Table 5 indicate that there are significant differences in concentration of available Potassium in soil irrigated with two different types of irrigation water, as concentrations in soil irrigated with wastewater increased significantly from 81.85 mg kg^{-1} before planting (Table 1) to 98.00 mg kg^{-1} after planting compared to soil irrigated with tap water, in which concentration of available Potassium reached 70.00 mg kg^{-1}. The increase in concentration of available Potassium in soil irrigated with wastewater may be due to increase in concentration of dissolved Potassium in wastewater (8.23 mg L^{-1}) (Table 2) compared to concentration of Potassium in tap water. These results are consistent with what was reported by Al-Mansouri *et al*. (2016) who showed an increase in Potassium concentration in soil irrigated with wastewater.

Increasing the concentration of macronutrients (NPK) and organic matter in wastewater is a good factor for using them in irrigation to reduce the amount of fertilizers added to these elements, provided that the necessary treatments are carried out on them and they are purified from harmful pollutants.

Conclusions

Irrigation with wastewater increased values of various soil properties and led to increased concentrations of Nitrogen, Phosphorus, and Potassium in soil.

Recommendations

1- Rational and efficient management of wastewater, and not discharging it into rivers or irrigating the soil directly without undergoing the necessary treatment.
2- Using modern technologies in wastewater treatment and increasing the capacity of treatment plants to keep pace with the increasing population growth.
3- Raising awareness among farmers and informing them of damage caused by irrigation with untreated wastewater.
4- Conducting more long-term future research to determine harms resulting from the use of wastewater for irrigation and safety of agricultural crops.

Refrences

- Abdul Karim, Khalifa Abdul Karim Misbah and Amhani Saleh Amhamed. 2021. A study of the effect of untreated sewage water on some soil properties in the Ajdabiya region, Libya. Journal of Humanities and Natural Sciences. Volume 2, Issue 12.

-Al-Ani, R. R., A. M. J. Al Obaidy, and F. M. Hassan, 2019. Multivariate analysis for evaluation the water quality of Tigris River within Baghdad City in Iraq. Iraqi Journal of Agricultural Sciences, 50(1): 331-342. https://doi.org/10.36103/ijas.v50i1.299

-Alsaadoon, D.W.K; F. M. Hassan and W. M. Mahdi.2024. ASSESSEMENT OF WATER QUALITY OF DIYALA RIVER USING OVERALL INDEX OF POLLUTION (OIP) IN IRAQ. Iraqi Journal of Agricultural Sciences – 2023:54(3):682- 690.

- Al-Saeedi, Sabah and Al-Aboudi, Fadel. 2010. Environmental study of some physical and chemical properties of Al-Gharraf River water in Dhi Qar

Governorate. Department of Life Sciences / College of Education / University of Dhi Qar, Nasiriyah, Iraq.

- Al-Tamimi, Haifa Jassim Hussein, 1997. Chemical behavior of chelated micronutrient fertilizers made from humic and common acids and their efficiency in some calcareous soils. PhD thesis, College of Agriculture, University of Basra.

- Al-Mansouri - Jamal Ali Qasim Saif and Mukhtar Dayel Muhammad Othman and Ahmed Muhammad Al-Wadaei. 2016. Estimation of quality indicators in soil irrigated with industrial wastewater in Al-Maraw'ah area in Al-Hodeidah - Republic of Yemen - Journal of the Association of Arab Universities for Agricultural Sciences, Ain Shams University, Cairo. Volume (24), Issue (2): 417-430.

- Al-Mashri, Khairiya Muhammad Ahmad. 2022. The impact of untreated wastewater on groundwater. International Journal of Science and Technology. Issue 30.

- Al-Mayah, W. T., and A. M. Rabee, 2018. Application of overall index of pollution (OIP) for the evaluating of the water quality in AlGharraf River southern of Iraq. Iraqi Journal of Sciences, 59(2A): 660-669

-Al-Obaidy AHM, Al-Janabi ZZ and Al-Kubaisi AR. 2014. The distribution of heavy metals in the Tigris River in central Iraq.Baghdad Journal of Science 11(2): 102-109.

-Al-Yasiri, Ali Abdul-Khabir Ali 2007. A study of the chemical and physical properties of different water sites in the areas of Suq Al-Shuyukh and Al-Jabaish in Dhi Qar Governorate. Journal of Dhi Qar University, 3 (3:) 103-107.

-Black, C.A.; D.D.Evans; L.E. Ensminger; J.L. White, and F.E.Clark. 1965. Methodsof Soil Analysis., Part l. Physical Analysis, American Soc. Agronomy. Inc. Madison Wisconsin. USA.

-García-Orenes, F.; F. Caravaca; A. Morugán-Coronado, and A. Roldán. 2015.Prolonged irrigation with municipal wastewater promotes apersistent and active soil microbial community in a semiarid agroecosystem. Agricultural Water Management, 149: 115-122.

- Harmoosh, Mona .2013. Effect of continuous irrigation with treated wastewater on some physical and chemical properties and heavy metal accumulation in soil and plants. Master's thesis, Al-Baath University, Syria.

- Hashim , Ayad Gh. 2017.The physico-chemical properties of southern part of Diyala River water. Iraqi Journal of Science, 2017, Vol. 58, No.4C, pp: 2222-2228. DOI: 10.24996/ ijs.2017.58.4C.7.

- Hassan, F. M., J. N. A. Al-Zubaidi, and O. S. Youssef, 2018. Limnological study of Diyala river, Iraq. Iraqi Journal of Agricultural Sciences, 49(3). pp: 452-462. https://doi.org/10.36103/ijas.v49i3.117 .
-Jackson, M. L. 1958. Soil chemical analysis. Prentice -Hall. Inc. Englewood. Cliffs N. J.
- Khan, M.A.; S.S. Shaukat and M.A. Khan .2009. Growth, yield and nutrient content of sunflower Helianthus annus L.using treated wastewater from waste stabilization ponds. Pak. J. Bot., 41(3):1391-1399.
- Militan, Abdul Majeed, Hanan Ahsouna, Khadija Al-Qunaidi, Khawla Abu Ruwais. 2019. A study of the effect of wastewater on some soil properties in the Sasso Valley area, Academic Research Journal 174-182.
- Milad, Ramadan Ali, Mustafa Ali Bin Zaqta, and Mahmoud Ayash Ima'rif. 2019. Effect of reusing treated wastewater in irrigation on some chemical properties of soil and growth of wheat crop. Misurata University Journal of Agricultural Sciences. Special issue of scientific papers submitted to the First Scientific Conference of Agricultural Sciences - Plant Production.
- Mohammed, Najla Ajil and Rajab, Israa Muwaffaq. 2017. A Study of Some Pollution Determinants of Three Wastewater Plants in Maysan Governorate for the Period (2013-2014). Journal of the College of Education. Al-Mustansiriya University. Issue Six. P. 473.
- Palese, A.M., G. Celano, S. Masi, and C. Xiloyannis.(2006).Treated wastewater for irrigation of olive trees: effects on yield and oil quality. In: OlivebioteqMazara del Vallo,. Marsala, Italy, pp. 123–129.
-Page, A. L.; R. H. Miller and D. R. Kenney. 1982. Methods of soil analysis, part (2).Chemical and Biological Properties .Am . Soc. Agro . Inc. Publisher, Madison,Wisconsin.
-Standard Methods.1995. The examination of water and wastewaters, American water Public Health Assoc., American water works Assoc. 19th ed., New York.
- Salman, J. M., and A. A. S. AlShammary, 2020. Monitoring lotic ecosystem by the application of water quality index (CCMEWQI). Baghdad Sciences Journal, 17(1). pp:23-27.
- Warraq, Hanaa Abdel Aziz Al Rashid and Mutawakil, Salah Mirghani. 2013. The effect of sewage water on the soil in Port Sudan city. Red Sea University Journal. Issue 3 (30): 18-9.