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IMPACT OF REUSING DRAINAGE WATER FOR IRRIGATION ON AGRO-ECOSYSTEM .

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ABSTRACT

The present study was carried out on EL-Gharbia main drain located in Middle Nile Delta. EL-Gharbia main drain passes through many villages dotted along it receiving their drainage water, house wastes, commercial activities and industerial effluents. Thus, six locations were selected along the drain from Nemra EL-Basal to the end of drain locations. Water samples were monthly collected during Sep.2010 to Aug.2011. Also, six sidement samples from each location, as well as, six soil samples and twelve plant samples were taken from fields which irrigated directly from the drain through winter and summer seasons.

The main obtained results are presented as follows:

- Electrical Conductivity (EC) values increased slightly with northward direction. Also, Sodium Absorption Ratio (SAR) took the same trend. All water samples, at all locations lie in C3S1 division except at the end of drain lie in (C4S2).
- For boron (B) concentration, the locations of Nemra EL-Basal, Dokhmaas, EL-Karakat and EL-Hamoul have low concentration (B1) < 0.7 meq/L less than the criticle limit which indicated “no-problem”. Whereas, the other locations were lie in (B2) > 3 meq/L which indicated “severe problem” for irrigation during the year of study.
- NH_4-N values, at all locations recorded less values than the critical level < 5 meq/L, which indicated “no-problem” except at the end of drain, which its values were “slight to moderate problem”. Also, for NO_3-N values, were less than < 10 meq/L in all studied locations, except at the end of drain which values were above the criticle level indicating “slight to moderate problem”.
- The values of chemical oxygen demand (COD) in samples were taken from Nemra EL-Basal to EL-Karakat were more than < 600 meq/L indicating “slight to moderate problem”. While, the other locations were less than 600 mg/L indicating “no-problem”. Also, the values of biological oxygen demand (BOD) in samples were taken from Nemra EL-Basal to the end of drain locations were less than 300 mg/L indicating “no-problem”.
- Lead content in water was low in the most months and at most locations from the permessible limits (5 mg/kg) with a slight increase in these values northwards on the downstream direction.
- Total lead in soil and sediment content was less than the permissible limits (500 mg/kg).
- Lead content in wheat and rice grain value was higher than the permissible limits (0.5 mg/kg).

Keywords: Drainage water, lead, agro-ecosystem.

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INTRODUCTION

The actual resources currently available for use in Egypt are 55.5 BCM/yr, and 1.0 BCM/yr effective rainfall on the northern strip of the Delta, non-renewable groundwater for western desert and Sinai, while water requirements for different sectors are in the order of 75 BCM/yr. The gap between the needs and availability of water is about 20 BCM/yr. This gap is overcome by reusing non-conventional water resources such as, agricultural drainage water. Reuse of drainage water become an essential element in water mangment starting in late 1980s. This reuse was made possible by the extensive network of open drains and subsurface drains. The drainage water use in irrigation were officially and non-officially. Official reuse is the practice of pumping part of the drainage water flow into the irrigation water system. Physically, official reuse occurs by lifting specified amounts of drainage water for mixing with better water quality canals. Unofficial reuse is practiced by indiviual farmers who decide, when and how drainage water will be used for supplementing their needs of irrigation water. Unofficial reuse of drainage water normally takes place near the tail ends of the irrigation canals.

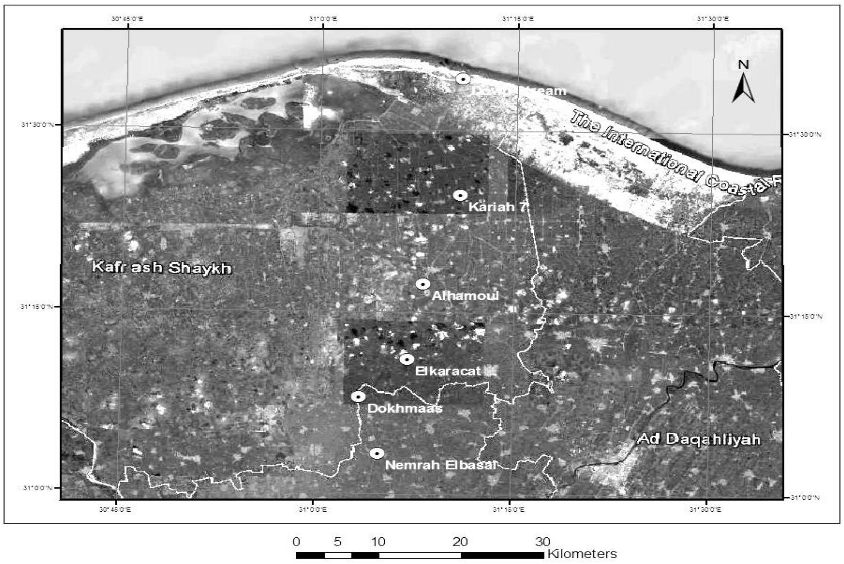
El-Gharbia main drainage system is one of the largest drainage systems in the Nile Delta. It is located in the central part of Middle Nile Delta and has a total catchments area of about 1,800 km^2. It originates in EL-Gharbia Governorate north of Tanta city and extends through Kafr EL-Sheikh Governorate in the north direction till it reaches the Mediterranean Sea at Balteem city. This drain considered the main source of irrigation to many lands in Kafer EL-Sheikh Governorate, where it suffers from shortage of water for irrigation. It receives drainage water from adjacent fields i.e drainage system of the irrigation, industerial and sewage, which are the main sources of pollution by heavy metals. The increase in heavy metal concentrations in the environment in the last decades is primarily due to erosion and anthropogenic activities, and because metals are very persistent pollutants, they accumulate in the soil, water sediments and in the food chain (Čelechovská *et al*., 2008).

Heavy metals are naturally present in abundance and enter the water cycle through a variety of geochemical process; many elements are also added to water by man induced activities such as manufacturing construction and agriculture. It is well recognized that process of heavy metal elements in the environment can be detrimental to a variety of living species, including; effects of such metals can be easily distinguished from other toxic pollutants (Schwartz and Rimkus, 1991). El-Shahawy and Ragab (2005) determined some heavy metals concentration in El-Gharbia main drain. The results illustrated that the concentration of Pb ranged between 0.02-0.25 mg/L. Pb content in the drainage water of EL-Gharbia main drain are less than standard levels for irrigation water.

In Egypt, many trials have been made, to evaluate both irrigation and drainage water with respect to the total soluble salts expressed in terms of electerical conductivity. Khalifa (1990) evaluated the water of EL-Gharbia main drain in Kafr EL-Sheikh and showed that, this water had alkalinity hazards. El-Shinnawy (2002) reported that, BOD and COD concentration in EL-Gharbia main drain ranged between (4.00-84.00 and 7.60-225.0 mg/L), respectively.

MATERIALS AND METHODS

The water samples were collected monthely during the period of September 2010 to August 2011, from six locations in EL-Gharbia main drain. These locations were distributed along the drain (Map 1). Six soil sediment samples were collected from the bottom of drain in the six locations i.e. Nemra El-Basal, Dokhmaas, El-Karakat, El-Hamoul, Village No.7 and at the end of drain. Also, samples from surface soil and crops (wheat and rice) irrigated by drainage water were collected and subjected to chemical analysis.



Map (1): Locations across at EL-Gharbia main drain under the present study:-

- **Water analysis**:- Salts content expressed as EC values were measured by using electrical conductivity meter, soluble cations and anions were determined according to Rhoades and Miyamoto (1980). Sodium adsorption ratio (SAR) was calculated using Richards's equation (1954). Chemical oxygen demand (COD) and biological oxygen demand (BOD) were measured according to (APHA, 1985). Nitrate (NO^-_3) and ammonia (NH^+_4) were measured by using automatic micro kjeldahl- 1035 Analyzer according to (APHA, 1985).Total phosphorous (meq/L) was measured by stannous chloride method using spectrophotometer as described by (APHA, 1998). Boron was determined colourmetrically using curiumen according to (Jackson, 1973). For determined Pb content in the drainage water of EL-Gharbia main drain, water samples were digested using nitric acid as described in standard methods – 302 A (APHA, 1985).

- **Soil and Sediment analysis:-** Soil and sediment samples were digested using a concentrated mixture of H_2SO_4 and $HCLO_4$ acids according to Jackson (1973). The available form of Pb was extracted using the extracted solution of diethylen triamine penta acetic acid 0.005 M (DTPA), calcium chloride ($CaCL_2$) and triethanol amine (TEA), according to Lindsay and Norvell (1978).
- **Plant analysis:-** Wheat and rice grain samples were dried, ground and digested using a concentrated mixured of H_2SO_4 and $HCLO_4$ at (5: 0.5) ratio as described by Chapman and Pratt (1961).
- Water and extracted soil, sediment and plant samples were were measured using GBC Σ Aventa vir 1.3 atomic absorption, for determined Pb content according to (Page *et al*., 1982).

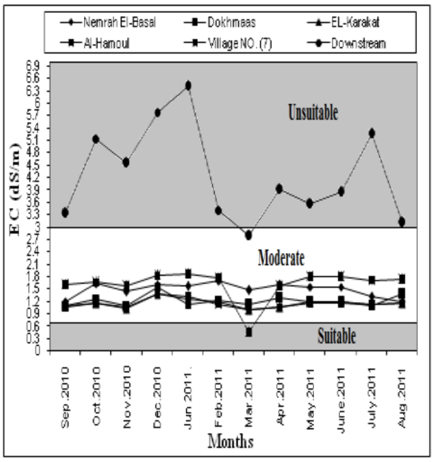
RESULTS AND DISCUSSION

Evaluation of EL-Gharbia main drain water for irrigation purpose:-

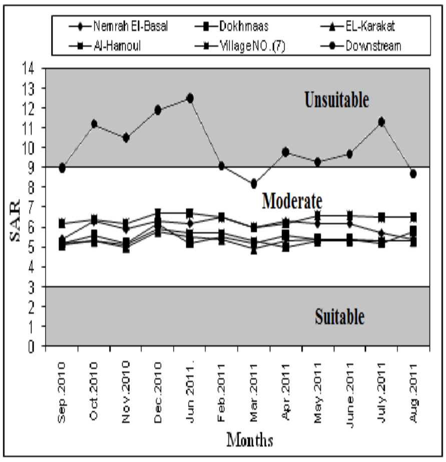
The suitability of drainage water for irrigation purpose was determined by salinity, permeability and toxicity problems.

The salinity problem:-

The potential salinity problem caused by salts in EL-Gharbia main drain is evaluated according to U.S. salinity laboratory (1954) and FAO (1985). As shown in Table (1) and Fig. (1), the drainage water could by classified into groups as follows: The first group includes water having EC content ranged between 0.75 to 2.25 $dS.m^{-1}$ at Nemra EL-Basal to Village No.7. This drainage water group belongs to C3-class in USSL classification and is considered to cause increasing salinity problem (FAO 1985). Therefore this water can not be used for irrigation with restricted drainage system. To use this water for irrigation adequate drainage system and special management for salinity control are required and plants with high salt tolerance should be selected. The second group includes water samples having EC values more than 2.25 $dS.m^{-1}$ at the end of drain. This drainage water group belongs to C4-class in USSL classification and not suitable for irrigation under ordinary conditions but may be used occasionally under very special circumstances.



Figure(1):EC in EL-Gharbia main drain water



Figure(2):SAR in EL-Gharbia main drain water

According to FAO (1985) guidelines, the water sample at Nemra El-Basal to Village No.7 locations were lie in " slight to moderate problem"but in the end of drain, indicates " Severe problems".

Generally, EC values were higher in winter than in summer. EC values were slightly increased from Nemrah El-Basal to EL-Hamoul locations and markedly incresed in the other locations (Village No.7 and the end of drain). The increase of EC value in winter than in summer may be due to the winter closure period where the supply of irrigation water to the main canals is stopped or low during this period. Also, the salinity of drainage water is lower in the summer than in the winter, probably because of large amounts of water discharged to the drains.

The permeability problem:-

Permeability problem is related to water infiltriation into and through the soil profile. The soil permeability is related to the effect of sodium concentration in irrigation water. As shown in Table (1) and Fig. (2), drainage water samples of EL-Gharbia main drain can be classified according to SAR into two groups. The first group (S1 < 10) for all locations except at the end of drain and it can be used for irrigation with little adverse effect of the development of harmful levels of exchangable sodium (Richard, 1954). The second group includes drainage water having SAR > 10. This group belong to S2-class for high EC water as an average values and it will cause sodium hazard in fine textured soil having high cation exchange capacity, especially under lower leaching conditions, unless gypsum is present in the soil.

According to USDA (1954) water of the studied sites is entirey S1-class from Nemra El-Basal to Village No.7. The description of this class " alkalinity hazard" for water as low concentration of sodium thus, this water can be used for irrigation in most months, with few adverse effects when using. However, sodium sensitive crops may accumulate injurious amounts of sodium.

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While, at the end of drain, water recorded during the period of this study entiery S2-class. It means that, water have medium sodium may be suitable for coarse textured or organic soil with good permeability.

According to (FAO, 1985) and as shown in Fig. (1 and 2), the drainage water at all studied locations except at the end of drain can be used in irrigation in winter and summer seasons where the samples lie in (slight to moderate salinity problems) class and SAR (S1 < 10).

Oxygen parameters “chemical oxygen demand (COD) and biological oxygen demand (BOD)”:

As shown in Table (1) and Fig. (3,4) data showed that, according to Egypt regulation (1994), COD values in the water samples from Nemra EL-Basal to EL-Karakat were more than < 600 meq/L which indicate “slight to moderate problem”. While, the other locations were less than 600 mg/L which indicate “no-problem”. Also, BOD values in the water samples from Nemrah EL-Basal to the end of drain locations were less than 300 mg/Lwhich indicate “no-problem” for irrigation use. That, this water can be used for irrigation as a raw water where the COD and BOD values not exceed 600 and 300 meq/L, respectively.

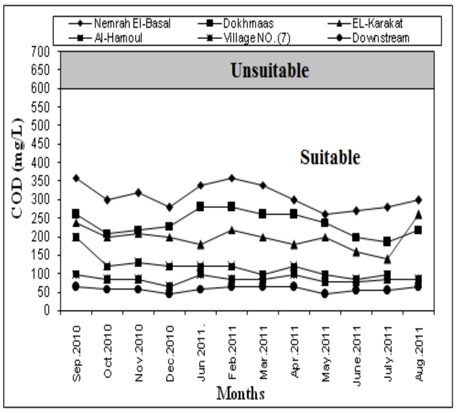

Figure (3): COD in EL-Gharbia main drain water

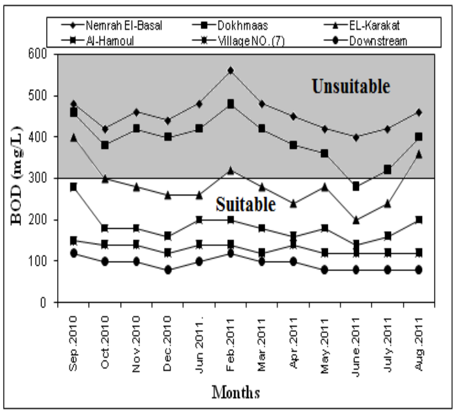

Figure (4): BOD in EL-Gharbia main drain water

The toxicity problem:-

- **Boron toxicity problem:-**

According to FAO (1985), data presented in Table (1) and Fig. (5) are showed that, the average concentration of water boron for Dokhmaas, El-Karakat and EL-Hamoul were in B1-class “less than < 0.7 meq/L” which indicat “no-problems” for irrigation use while, the rest locations lie in B2-class “increasing problems” during the year of study.

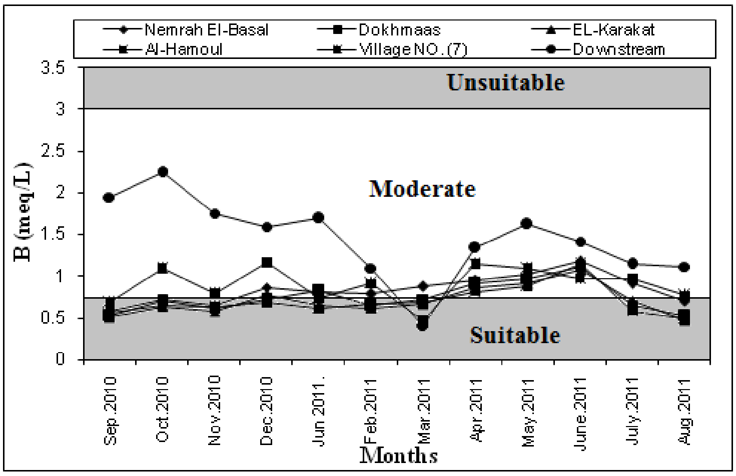

Figure (5): B in EL-Gharbia main drain water.

According to Gupta (1979), this water belongs to class B1 < 3, i.e., "normal water". This water can be used for most of tolerant and semi-tolerant crops to boron in all soils without any injuries effects on grain yield. Boron concentration in the water generally was increased with increasing salts content. According to FAO (1985), this water can be classified as "slight to moderate" degree of restriction on use".

Nitrate and Ammonium toxicity:-

Data in Table (1) and Fig. (6,7) reveal that, according to FAO (1985) guidelines, all water samples from the studied locations indicate "no problem" (less than 5 meq/L) for NH_4-N values. Whereas, the NO_3-N values were less than 10 meq/L for all locations except at the end of drain indicate "no-problem" for irrigation use. This water can be used in irrigation without any problem according to guidelines of FAO (1985). But, at the end of drain, NO_3-N values were above the critical levels (10 meq/L), which indicate "slight to moderate problems".

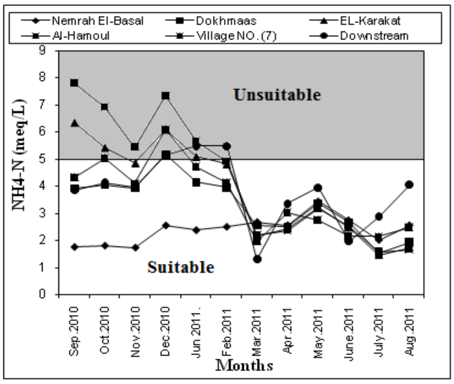

Figure (6): NH_4-N in EL-Gharbia main drain water

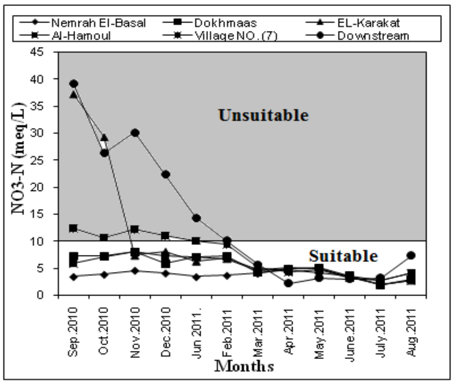

Figure (7): NO_3-N in EL-Gharbia main drain water

The toxicity problem induced by Pb:-

The values of Pb were slightly increased from Nemra El-Basal to El-Hamoul locations and markedly increased in the other locations Village No.7 and at the end of drain, Table (1) and Fig. (8). It was observed that the values were increased with the north direction. The Pb values in summer season were higher than in winter season compared to the spring and the autumn seasons.

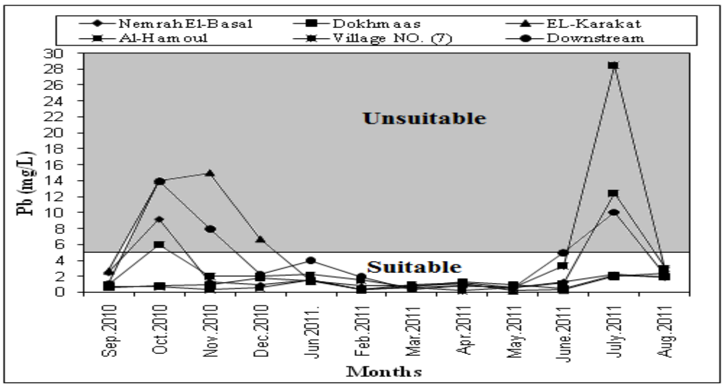

Figure (8): Pb in EL-Gharbia main drain water

According to FAO (1985), the mean values of Pb concentration for EL-Gharbia main drain from Nemra EL-Basal to the end of drain locations are less than the critical limits (5 mg/L). Whearas, some locations recorded high limits in some months such as, Nemra EL-Basal in Oct.2010, EL-Karakat in Oct. to Dec.2010, EL-Hamoul in July 2011, Village No.7 in Oct.2010 and July 2011 and the end of drain in Oct. Nov.2010 and July 2011.

Lead (Pb) content in the sediments of El-Gharbia main drain:-

Most trace elements, especially heavy metals, such as (Pb) does not exist in soluble form for a long time in waters. They are present mainly as suspended colloids or fixed by organic and mineral substances. Thus, their concentrations in bottom sediments or in plankton is often an adequate indication for water pollution by trace elements. Data presented are in Table (2), showed that the values of total Pb decreased at downward. Also, the values of DTPA-extractable Pb took the same trend. Svobodová *et al*., (2002) found that bottom sediments, aquatic macrophytes and invertebrates are very important links in metal cycles in the aquatic environment and they are commonly used in the biomonitoring of heavy metals. Generally, sediments can accumulate large amounts of heavy metals and become their main reservoir in the wetlands.

Lead (Pb) content in soils irrigated directly from EL-Gharbia main drain:-

Total Lead content

Data presented in Table (2), showed the total amounts of Pb was affected by irrigation with drainage water. Data reveal that, the total content of Pb are differ according to locations and soil textures along EL-Gharbia main drain. The total values of Pb from Nemrah EL-Basal to the end of drain locations were (55, 55, 65, 77.5, 55 and 47.5 $mg.kg^{-1}$), respectively. It can be observed that, this metal seems to be fixed in the soil and tended to accumulate in the topsoil. The increasing in total amounts of lead could be mainly due to repeating irrigation with drainge water. It should be mentioned that, mismanagement of wastewater irrigation especially under long term application can led to toxicity problems by heavy metal (Pb) and high levels of nutreint accumulation and deterioration of soil and crop quality parameters. Papadopoulos (1995) found that accumulation of heavy metal from wastewater application could be caused directly from the wastewater composition or indirectely through increasing solubility of the insoluble soil heavy metals as a result of the chelation or acidification action of the applied wastewater. Mosalem (1997) revealed that increasing irrigation period of sewage effluent at EL-Gabal EL-Asfer farm has increased both DTPA extractable and total Pb element in soil sample. In agricultural soils, Pb could also be increased from the application of agrochemicals. concentrations over (100-500 mg/kg) would represent potentially contaminated soils, (Kabata-Pendias and Pendias, 2001).

DTPA-extractable lead (Pb)

Results given in Table (2), showed the DTPA-extractable Pb in the soil after harvesting wheat and rice plant during winter 2010 and summer 2011 as affected by irrigation with drainage water for EL-Gharbia main drain from Nemrah EL-Basal to the end of drain locations. The values of the available lead were varing according to different locations, type of cultivated plants and soil texture. Several authors reported that solubility of most heavy metals dissolution and precipitation processes of soil minerals are controlled by soil pH (Elinder *et al*., 1988). Althogh other soil scientistis believe that soil chemistry is also very important in controlling the solubility of trace elements in the long-term (FAO, 1981) pay no heed to the characteristics of the soil. The DTPA-Pb values from Nemrah EL-Basal to the end of drain locations were (10.88, 0.88, 1.2, 14.08, 8.8 and 0.84 $mg.kg^{-1}$), respectively. This indicates that the increases in total heavy metals contents in the soil are in accordance with extractable by the DTPA.

Impact of using drainage water on plant:

The contents of Pb in grains of wheat plants grown in the soil as affected by irrigation with drainge water for EL-Gharbia main drain from Nemra EL-Basal to the end of drain locations after harvesting are shown in Table (2). In general, Pb contents in grains were similar for all locations except for Nemra EL-Basal which recorded the higher value (4.8 ppm). While, in grains of rice plant, the content of Pb in all locations of study were (1.3, 0.4, 0.3, 2.2, 3.3 and nd $mg.kg^{-1}$), respectively.

The maximum Pb limit for human health has been established for edible parts of crops by WHO standard is (0.3 $mg.kg^{-1}$) (Codex, 2001). Data showed that in all plants, lead concentration is more than the permitted level, so these plants are not suitable for consumption. Wierzbicka (1995) showed that, in many plants Pb accumulation can exceed several hundred times the threshold of maximum level permissible for human. On the whole, all plants investigated were contaminated by lead and they were toxic to consumer.

Table (2): Lead contents in sediments, tested soil and plants (mg.kg^{-1}).

Locations	Sediments		Soil		Conc. Pb in Grains	
	Total	DTPA	Total	DTPA	Wheat	Rice
Nemrah EL-Basal	22	2.12	55	10.88	4.8	1.3
Dokhmaas	19.8	2.96	55	0.88	1.9	0.4
EL-Karakat	20.2	2.02	65	1.2	1.8	0.3
AL-Hamoul	16	1.32	77.5	14.08	1.8	2.2
Village No. (7)	14.4	1.16	55	8.8	2.0	3.3
Downstream	13	1.02	47.5	0.84	1.6	nd

***Kabata Pendias and Pendias (1992).**

Conclusion

To safe reuse this water in irrigation, it is recommended that:

- This water can be used at the head of the drains where the salinity levels of waters were approximatly low.
- This water can be use in the summer season than in winter season compared to the spring and the autumn seasons where EC, SAR, COD, BOD, B, NH_4, NO_3 increased with the north direction for almost at Nemra EL-Basa, Dokhmaas, EL-Karakat and EL-Hamoul except for Village No.7 and the end of drain locations. Whearas, this water can not be used for high Pb content in autumn and summer seasons for most of these locations.
- The water at the end part (downstream) of the studied drain is not suitable for irrigation during the period of studied (2010-2011).
- Proper management for water, soil and plant is needed to maximize drainage water utulization efficiency and to minimize the adverse effects. The soil must be permeable, drainage must be adequate, and irrigation water must be applied in excess amount to provide considerable leaching and high salt tolerance crops should be selected.

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USDA (1954). Diagnosis and improvement of saline and alkali soils. USDA, USA, Hand Book, No 60. vegetables (spinach and cauliflower) at Faisalabad. J. Drainage Reclam. 7:7-12.

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أثر اعادة استخدام مياه الصرف لأغراض الري علي النظام البيئي الزراعي.

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أجريت هذه الدراسة علي مصرف الغربية الرئيسي الذي يقع في وسط دلتا النيل حيث يمر خلال العديد من القري التي تنتشر علي طول هذا المصرف. يستقبل مياه الصرف الصحي ، مخلفات المنازل ، نواتج الانشطة التجارية والنفايات السائلة. ولهذا فقد تم اختيار ستة مواقع علي طول مصرف الغربية الرئيسي من نمرة البصل حتي المصب حيث تم تجميع عينات المياه شهريا من سبتمبر 2010 حتي أغسطس 2011. كذلك تم أخذ6 عينات رواسب نهرية و 6 عينات تربة و12 عينة نبات خلال شتاء وصيف فترة الدراسة من نفس المواقع التي تروي مباشرة من مصرف الغربية الرئيسي.

وكانت أهم النتائج المتحصل عليها:

- أظهرت قيم التوصيل الكهربي (EC) زيادة طفيفه مع الاتجاه شمالا حتي الوصول للمصب كذلك نسبة الصوديوم المدمص (SAR) أخذت نفس الاتجاه وعليه وقعت كل عينات المياه في كل المواقع في رتبة C3S1 باستثناء عينات المياه عند المصب وقعت في رتبة C4S2.
- بالنسبة لتركيز البورن ، بينت النتائج أن تركيزه في كل من مواقع نمرة البصل ، دخميس، الكراكات و الحامول كان منخفضا (B1) أقل من 0.7 مليمكافئ /لترحيث لا تسبب تركيزاته أي مشكلة عند الري بينما في المواقع الاخري وقعت تركيزاته في رتبة (B2) أكبر من 3 مليمكافئ /لتر وبالتالي قد يترتب علي ذلك ظهور مشاكل سمية عند الري.
- سجلت قيم الامونيا في كل المواقع نتائج أقل من المستويات الحرجة لها وبالتالي لا يوجد مشكلة بينما كانت تركيزتها مرتفعة عند المصب أما بالنسبة لقيم النترات فقد سجلت في كل المواقع نتائج اقل من المستوي الامثل 10 مليمكافئ/لتر فيما عدا المصب كانت تركيزات النترات به أعلي من المسموح به.
- أظهرت قيم الاكسجين المستهلك كميائيا (COD) في العينات المأخوذه من نمرة البصل الي الكراكات نتائج أعلي من 600 مليكافئ / لتر. بينما سجلت في المواقع الاخري نتائج أقل من 600 مليمكافئ / لتر كذلك أظهرت قيم الاكسجين المستهلك بيولوجيا (BOD) في العينات المأخوذه من نمرة البصل الي المصب نتائج اقل من 300 مليمكافئ / لتر.
- انخفاض قيم عنصر الرصاص في معظم المواقع ومعظم الشهور عن الحد المسموح به (5 مليجرام/كجم) مع زيادة طفيفه في هذه القيم بالاتجاه شمالا ناحية المصب.
- أظهرت نتائج تحليل الرصاص الكلي في التربة والرواسب النهرية قيم أقل من الحدود المسموح بها (500 مليجرام / كجم).
- أظهرت نتائج تحليل الرصاص في حبوب القمح والارز قيم أعلي من الحدود المسموح بها (0.5 مليجرام / كجم).

قام بتحكيم البحث

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Table (1): Water chemical and biological analysis and evaluation of El-Gharbia main drain during September 2010 to August 2011.

Location	EC dS/m			SAR			(meq/L)																	
							NH_4-N			NO_3-N			COD			BOD			B			Pb		
	*L	**H	***Mean	L	H	Mean	L	H	Mean	L	H	Mean	L	H	Mean	L	H	Mean	L	H	Mean	L	H	Mean
Nemra EL-Basal	1.19	1.71	1.49	5.4	6.5	6.01	1.75	3.44	2.4	2.77	4.77	3.92	260	360	309.17	400	560	455.83	0.58	1.18	0.84	0.3	9.2	1.90
Dokhmaas	1.09	1.56	1.12	5.25	8	4.98	1.54	5.18	3.32	2.05	8.13	5.52	185	280	237.08	280	480	393.33	0.52	1.12	0.75	0.3	2.1	1.09
El-Karakat	0.99	1.39	1.16	5	5.8	5.31	1.47	6.35	3.85	1.92	37.33	9.85	140	260	199.58	200	400	285	0.47	1.07	0.71	0.2	15	3.95
El-Hamoul	1.01	1.41	1.17	5	5.9	5.34	1.59	7.83	4.31	1.98	8.16	5.46	85	200	119.58	140	280	185	0.49	1.14	0.70	0.3	12.4	1.90
Village No.7	1.46	1.87	1.70	6	6.6	6.42	1.98	6.1	3.59	2.83	12.48	7.56	80	100	86.25	120	150	130.83	0.48	1.15	0.90	0.2	28.5	4.2
Downstream	2.78	6.42	4.26	8.2	12.5	10.1	1.32	5.5	3.81	2.26	39.26	13.98	45	66	58.83	80	120	95	0.41	2.24	1.45	0.6	14	4.2
C.L.	0.7 - 3[a]			3 - 9[b]			5[c]			10[d]			600[e]			300[f]			0.7 - 3[g]			5[h]		

L*: Lowest values H: Highest values ***Mean: Mean values of tewelve months**
C.L. : Criticle Limits: a, b, c, d, g, h and j according to FAO (1985) & e, f according to Egypt regulation (256) (1994).