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Assessment of waste waters quality for irrigation purposes

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Abstract

Reuse of wastewaters for irrigation purposes represents an additional source of those available to overcome the gap in quantity of irrigation water in Egypt. Such a gap is expected to increase after construction of Renaissance Dam in Ethiopia. However, evaluation of suitability of these waste waters for irrigation should be a matter of concern and should be carried out periodically owing to the variations of amounts and types of contaminants disposed in these waters. Therefore, the current investigation is a case study on waste water samples taken from inlets and outlets of Arab Abo-Saed, El-Gabal El-Asfer, Abo-Rawash and El-Berka treatment plants. These waters were analyzed for pH, total suspended solids (TSS), electrical conductivity (EC), soluble ion contents, heavy metal contents (Cd, Ni and Pb), boron content (B),.Also, NH_4-N and NO_3-N, biological oxygen demand (BOD_5) and chemical oxygen demand (COD) beside of total coliform were determined. Evaluation of the investigated waste waters was executed through determining of the hydrogen ion activity, salinity hazards, sodium hazards and miscellaneous hazards. All the investigated waste waters were of high salinity, low sodicity and very minute contents of the heavy metals and boron and hence can be used for irrigation after taking into account the leaching requirements and type of the crop to be irrigated. However, total coliform bacteria exceeded the permissible limits and more efficient treatment should be followed to protect human health against these bacterial contaminants.

Keywords: wastewater, contaminants, irrigation water quality, suitability.

Introduction

Water pollution occurs when pollutants are directly or indirectly discharged into water bodies without adequate treatment to remove harmful compounds and it affects plants and organisms living in these bodies of water. In almost all cases, the effect is damaging not only to individual species and populations, but also to the natural biological communities **(Laws, 2000).** Water pollution can be defined in many ways, usually, it means one or more substances have built up in water to such an extent that they cause problems for animals or people **(Woodford, 2006).** Population explosion, disorderly rapid movement to the urban areas, technological and industrial expansion, energy utilization and waste generation from domestic, municipal and industrial sources have rendered many waters unwholesome and hazardous to man and other living things.

Sustainable development of water resources involves considerations of population growth, urbanization, industrialization, land use practices, climate change and water recycling **(McCarton and Hogain, 2013)**. Approximately 40% of world food is produced by irrigated crops, sustaining the livelihood of billions of people.

In order to sustain irrigation, large amounts of water are withdrawn from rivers, lakes, reservoirs, and groundwater, together making up about 70% of global water withdrawals **(Famiglietti, 2011).**

Numerous parameters are used to define irrigation water quality and assess salinity hazards to determine appropriate management strategies **(Tanji, 1990)**. For irrigated agriculture, numerous classifications for water use have been developed, each with certain suitability, although none has proved entirely satisfactory. The prevailing criteria of irrigation water quality and their associated potential hazards to crop growth are: salinity, alkalinity (sodicity), toxicity, and miscellaneous (**Ayers and Westcot, 1994; Hakim et al., 2009 and Bauder et al., 2013).** However, the two most important measures for determining irrigation water quality are: the total amount of dissolved salts in the water and the amount of sodium (Na^+) in the water compared to calcium (Ca^{2+}) plus magnesium (Mg^{2+}) (**Johnson and Zhang, 2013).**

Wastewater is water that has been used and must be treated before it is released into another body of water, so that it does not cause further pollution of water sources. Wastewater comes from a variety of sources. Wastewater treatment is a process whereby the contaminants are removed from wastewater as well as household sewage, to produce waste stream or solid waste suitable for discharge or re-use **(Naik, 2010).** Wastewater treatment is the removal of solids, bacteria, algae, plants, inorganic and organic compounds from used water with subsequent conversion into environmentally acceptable water or even drinking water. In many studies worldwide the use of treated sewage effluents (TSE) as water and nutrient sources in agricultural irrigation have been introduced as a viable alternative for wastewater destination in the environment. Various studies have revealed that the nutrient supply only by TSE irrigation was not sufficient to meet plant nutrient requirements resulting in yield decreases **(da Fonseca et al., 2007)**. Sewage, often untreated, is used to irrigate 10% of the world's crops, according to the first over global survey of wastewater irrigation **(Scott et al., 2004).**

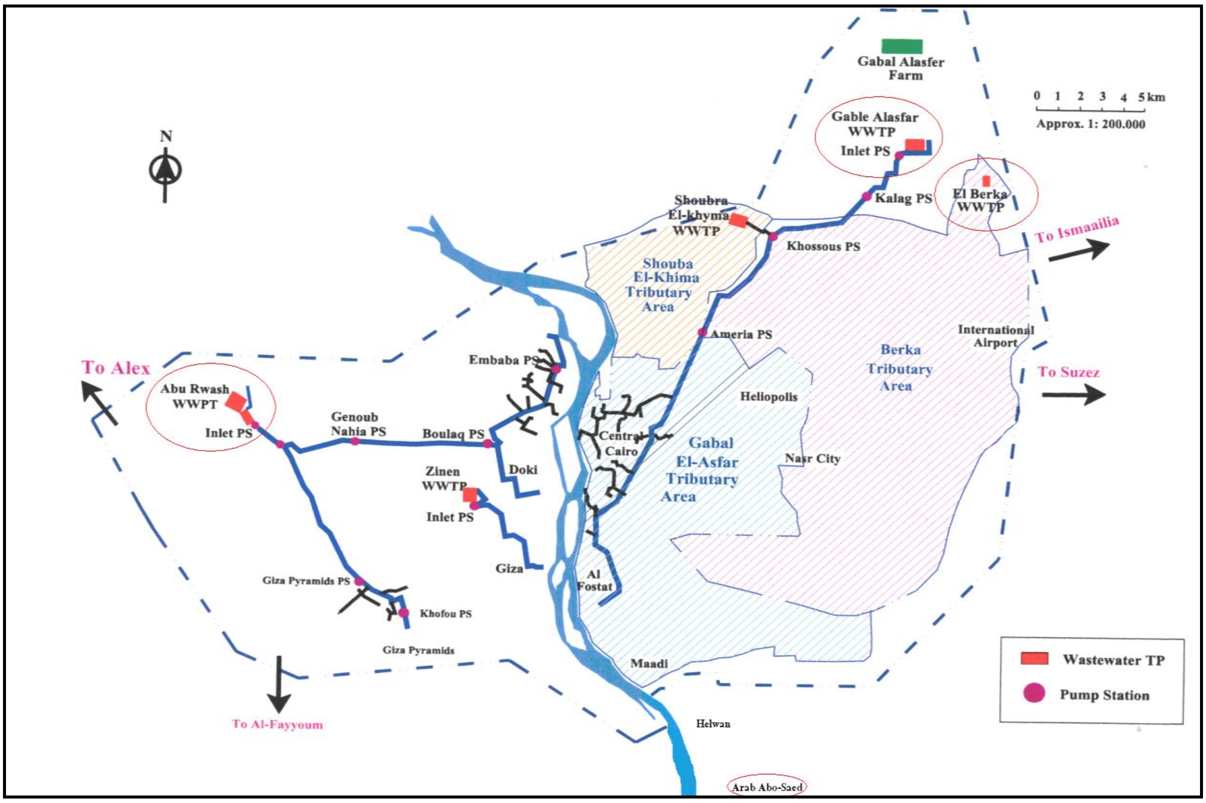
Impact from wastewater on agricultural soil, is mainly due to the presence of high nutrient contents (nitrogen and phosphorus), high total dissolved solids and other constituents such as heavy metals, which are added to the soil over time. Wastewater can also contain salts that may accumulate in the root zone with possible harmful impacts on soil health and crop yields. The leaching of these salts below the root zone may cause soil and groundwater pollution **(Bond, 1999).** Wastewater induced salinity may reduce crop productivity due to general growth suppression, at pre-early seedling stage, due to nutritional imbalance, and growth suppression due to toxic ions **(Kijne et al., 1998).** The impact of wastewater irrigation on soil may depend on a number of factors such as soil properties, plant characteristics and sources of wastewater. The impact of wastewater from industrial, commercial, domestic, and dairy farm sources are likely to differ widely **(Degens et al., 2000).**

The current investigation represents a trial towards assessing suitability of some waste waters (treated and untreated) for the agricultural purposes through determining the main features controlling this suitability.

Materials and Methods

Location and collection of the wastewater samples.

The investigated wastewater samples were taken from inlets and outlets of Arab Abo-Saed, El-Gabal El-Asfer, Abo-Rawash and El-Berka treatment plants. Map 1 shows locations of the investigated wastewater treatment plants.



Map 1: Locations of the investigated waste water treatment plants.

Water analysis.

Field measurements

Electrical conductivity and pH were measured immediately at the sample point (in situ).

Laboratory analysis

Water samples were collected from the designed monitoring locations and transported to the laboratory. The water samples were analyzed for dissolved constituents in the laboratory to determine water quality parameters, including soluble cations (Na^{+}, Mg^{2+}, Ca^{2+}, K^{+}) , soluble anions (CO_3^{2-}, HCO_3^{-}, chloride Cl^{-} and nitrate NO_3^{-}) beside of boron and heavy metals (Cd, Ni and Pb). Also, biochemical oxygen demand (BOD) and chemical oxygen demand (COD) were determined.

Methods of analysis of water samples

The water samples were analyzed for dissolved constituents in the laboratory according to the standard methods outlined by **Page et al. (1982)** as follows:

- pH was immediately determined at the sampling points using pH meter, model pH con-10 series, Cole Parmer.
- Electrical conductivity (EC) was determined by digital electrical conductivity meter, Model 33 S-C-T meter YSI.
- Calcium and magnesium by titration against ethylene di-amine tetra-acetic acid (EDTA) using murexide and EBT as indicators, respectively.
- Sodium and potassium photometrically using digital flame analyzers (Models, 2655.00.Cole Parmer).
- Carbonate and bicarbonate by acid titration using phenolphthalein and methyl orange as indicators, respectively.
- Chloride was determined by Mohr's method.
- Sulfate were calculated by subtracting the total determined soluble anions from the total soluble cations.
- Heavy elements (Cd, Ni and Pb) were determined using Atomic Absorption Spectrophotometer (Percin-Elmer, Model 2308).
- Boron was determined by UV/visable spectrophotometer (Model, UV-1601 A), at 600 nm.
- Biological oxygen demand (BOD_5) and chemical oxygen demand (COD) were determined according to the standard methods outlined by **Gupta (2007).**

Results and Discussion

Main chemical features of the investigated wastewaters:

Water pH

Data presented in Table 1 reveal that pH values of the investigated wastewater samples ranged from 7.35 to 7.88. Generally, higher pH values characterized the waste waters at the inlets of both El-Gabal El-Asfar and Abo-Rawash treatment plants, while, on the other hand, the lowest value characterized the inlet of Arab Abo-Saed treatment plant. The differences in the pH values among the inlets and outlets of the treatment plants seemed highest and reached 0.37 units at El-Gabl El-Asfer. Contrary to that, the difference in pH value between the inlet and outlet of Abo -Rawash treatment plant was as low as 0.08 unit. Such variations in pH value can be probably attributed to the differences in wastewater treatment procedures in the studied treatment plants. It is worthy to note that pH outside the normal range (6.5 to 8.4) may cause a nutritional imbalance or may increase concentrations of toxic ions **(Ayers and Westcot, 1994).**

Total suspended solids (TSS)

Data in Table 1 reveal that values of TSS at the inlets of the studied treatment plants were far higher than those at the corresponding outlet ones. TSS values were 197, 343, 176 and 235 mg L^{-1} at the inlets of Arab Abo-Saed, El-Gabl El-Asfer, Abo-Rawash and El-Berka treatment plants, respectively. These values decreased to 21, 26, 53 and 76 mg L^{-1} at the outlets of the treatment plants, respectively. This indicates to the effective role of all the studied treatment plants in reducing values of TSS to values lower than those of the corresponding ones at the inlets.

Table 1. Chemical properties of raw and treated wastewater samples.

Location		pH	TSS, mg L^{-1}	EC, dSm^{-1}	TDS, mg L^{-1}	Soluble anions, mmolc L^{-1}				Soluble cations, mmolc L^{-1}			
						CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
L1	**inlet**	**7.35**	**197**	**0.80**	**512**	**0.00**	**0.60**	**10**	**4.48**	**2.0**	**2.4**	**10.32**	**0.36**
	outlet	**7.56**	**21**	**0.74**	**473.6**	**0.00**	**0.60**	**12**	**2.12**	**2.2**	**2.2**	**9.96**	**0.36**
L2	**inlet**	**7.51**	**343**	**0.90**	**576**	**0.00**	**0.80**	**9**	**4.44**	**3.4**	**1.2**	**9.23**	**0.41**
	outlet	**7.88**	**26**	**0.82**	**524.8**	**0.00**	**0.60**	**9**	**4.53**	**2.6**	**2.2**	**8.92**	**0.41**
L3	**inlet**	**7.42**	**176**	**0.99**	**633.6**	**0.00**	**1.00**	**5**	**4.79**	**2.2**	**1.4**	**6.83**	**0.36**
	outlet	**7.50**	**53**	**0.91**	**582.4**	**0.00**	**0.80**	**5**	**4.34**	**2.2**	**1.0**	**5.63**	**0.31**
L4	**inlet**	**7.41**	**235**	**0.80**	**512**	**0.00**	**3.4**	**2.70**	**1.87**	**2.95**	**1.42**	**3.3**	**0.39**
	outlet	**7.60**	**76**	**0.77**	**492.8**	**0.00**	**2.79**	**3.60**	**1.61**	**3.50**	**1.25**	**2.84**	**0.41**

L1: Arab Abo-Saed ; L2: El-Gabl El-Asfer; L3: Abo-Rawash; L6 : L4: El-Berka
TSS: Total suspended solids, EC: Electrical conductivity, TDS: Total dissolved solids

Electrical conductivity values (EC) and total dissolved salt contents (TDS).

It seems that the wastewater treatment did not affect electrical conductivity of the investigated wastewaters where the differences between EC values of these waters at the inlets and the corresponding ones at the outlets did not exceed 0.03 dSm^{-1} only in El-Berka treatment plant, while in the other three treatment plants differences were almost slightly higher and reached 0.06, 0.08 and 0.08 dSm^{-1} in Arab Abo-Saed, El-Gabl El-Asfer and Abo-Rawash treatment plants, respectively. Values of the dissolved salts (TDS) varied from a treatment location to another and also between inlets and outlets of the studied treatment plants. However, these values were generally small and ranging from 473.6 to 633.6 mgL^{-1}. Such a slight variations is expected since the studied treatment plants did not involve any process for desalinization of water.

Soluble ion contents

Table 1 illustrates that Na^+ ions dominated the cationic composition of all the investigated wastewaters, whether at the inlets or the outlets of the wastewater treatment plants. In most of the investigated wastewaters, Ca^{2+} followed Na^+ in concentration then Mg^{2+} and finally K^+ except for Arab Abo-Saed treatment plant where Mg^{2+} exceeded Ca^{2+}. No obvious effect was detected due to the treatments of the investigated wastewaters on ion concentrations, i.e. their concentrations at the outlets did not differ widely from their corresponding concentrations at the inlets.

The anionic composition of all the investigated wastewaters followed the decreasing order: $Cl^- > SO_4^{2-} > HCO_3^-$ except for El-Berka treatment plant, where the order was $HCO_3^- > Cl^- > SO_4^{2-}$. The CO_3^{2-} anions were not detected in any of the investigated wastewaters.

The aforementioned results show that the treatments of the wastewaters in almost all the investigated water treatment plants did not affect the ionic composition of the studied wastewaters. This finding is in line with the results obtained before, which revealed that EC values of the investigated wastewaters were not affected by the treatment plants.

Micellenous features of the investigated waste waters.

Heavy metal contents

Municipal wastewater may contain a number of heavy elements because under particular conditions wastes from many and informal industrial sites are directly discharged into the common sewer system. Thus, these wastewaters should be checked for trace element toxicity hazards, particularly when trace elements contamination is suspected **(Pescod, 1992)**. Data presented in Table 2 and Fig. 2 reveal that, all the investigated heavy metals i.e. Cd, Ni and Pb were found in either not detectable concentrations or very minute ones. It seems that the concentrations of these metal ions at the inlets of the wastewater treatment plants were almost equal to or slightly exceeded their corresponding concentrations at the outlets, However it can be noticed that concentrations of these metals whether at inlets or the outlets followed the decreasing order Pb > Ni > Cd.

Boron content

Data presented in Table 2 and Fig. 1 reveal that boron content in the investigated wastewaters varied from 49 to 208 µgL^{-1} being highest at the intlet of El-Gabl El-Asfer treatment plant and lowest at Abo-Rawash treatment plant outlet.

Table 2. Heavy metal and boron contents of the investigated wastewaters.

Location		Heavy metal Cd	Ni	Pb	Boron content
		Concentration µgL^{-1}			
L1	**Inlet**	**0.1**	**2.9**	**5.7**	**127**
	Outlet	**ND**	**0.9**	**5.0**	**114**
L2	**Inlet**	**0.5**	**5.2**	**7.7**	**208**
	Outlet	**0.1**	**3.3**	**6.4**	**128**
L3	**Inlet**	**0.2**	**1.4**	**5.4**	**66**
	Outlet	**ND**	**1.2**	**4.6**	**49**
L4	**Inlet**	**0.1**	**1.3**	**2.2**	**94**
	Outlet	**ND**	**1.1**	**1.2**	**76**

See footnotes of Table 1.

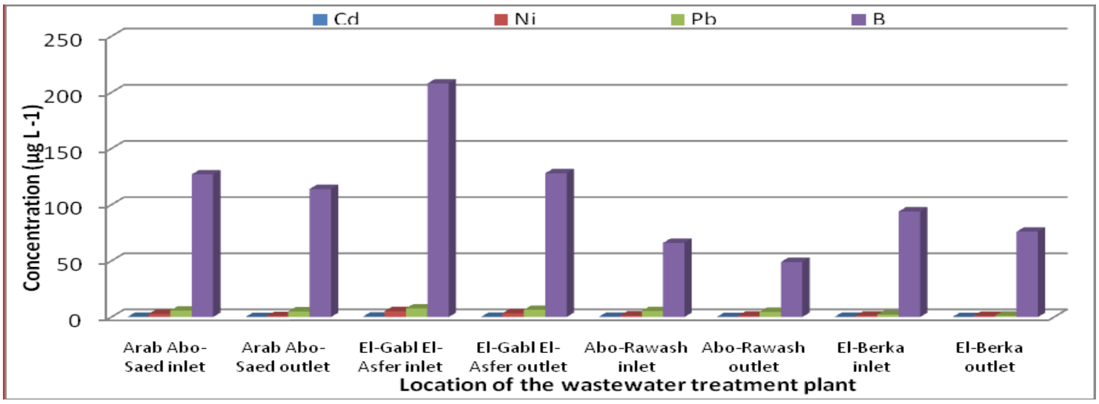


Fig.1: Heavy metal and boron contents of the investigated wastewaters.

Biological oxygen demand (BOD_5)

This is defined as the amount of oxygen consumed by the microbial decomposition of organic matter during 5 days incubation period. The lower the BOD_5 value, the better is the water quality **(Tan, 1994)**. Values of biological oxygen demand (BOD_5) presented in Table 3 were generally higher at the inlets than at the outlets of all the treatment plants indicating the efficiency of these plants in reducing values of these important parameter. BOD_5 at the inlets of Arab Abo-Saed , El-Gabl El-Asfer, Abo-Rawash and El-Berka treatment plants were 330, 525, 180 and 388 mgL^{-1}. Aeration process could reduce these values to 27, 32, 105 and 15 mgL^{-1}, respectively.

Chemical oxygen demand (COD).

This is defined as the amount of oxygen consumed in the chemical oxidation of organic matter by $K_2Cr_2O_7$ in the presence of H_2SO_4. Data presented in Table 3 reveal that the values of COD were generally higher in the inlets of investigated wastewater treatment plants than in their corresponding outlets. At the inlets, the studied plants can be arranged according to their COD in the following decreasing order El-Gabl El-Asfer > Arab Abo-Saed > El-Berka > Abo-Rawash. COD of these inlets ranged from 400 to 1295 mgL^{-1}. On the other hand, the corresponding COD values at the outlets ranged from 35 to 188 mgL^{-1}, being lowest at the outlet of El-Gabl Al-Asfer treatment plant and highest at the outlet of El-Berka treatment plant. Such a finding probably indicates to more efficient aeration process in El-Gabl El-Asfer treatment plant than the other studied treatment plants.

Ammonium and nitrate – N contents.

Values of NH_4–N presented in Table 3 seemed higher at inlets than the corresponding outlets where they ranged from 16.6 to 29.6 mgL^{-1} at the inlets corresponding to 2.4 to 14.4 mgL^{-1} at the outlets. This finding is probably attributed to oxidation of the NH_4^+ to NO_3^- by the action of the micro organisms previously activated due to aeration such as some kinds of bacteria i.e. Nitrosomonas and Nitrobacter.

NO_3^--N content took an opposite trend to that of NH_4^+, where its concentration values were lower at inlets than the corresponding concentration values at the outlets. Oxidation of NH_4^+ at the aeration basin may account for such increases in NO_3^-. It is worthy to note that, generally, NO_3^--N concentrations was less than NH_4^+-N concentrations at the inlets of the investigated treatment plants while the opposite was true at the corresponding outlets.

Total Coliform

Coliforms commonly occur in the water and generally not harmful to humans but their presence is used as an indicator for water contamination with diseases causing germs and pathogens. Values of total coliform presented in Table 3 illustrate that, their count varied from 4700 to 6200 cuf/100mL at the inlets of investigated waste water treatment plants corresponding to 1200 to 2200 cuf/100mL at the outlets.

Table 3. Miscellaneous features of the investigated wastewaters**.**

Property	Location of the wastewater treatment plant							
	L1		L2		L3		L4	
	inlet	Outlet	inlet	outlet	inlet	outlet	inlet	outlet
BOD, mg/L	**330**	**27**	**525**	**32**	**180**	**105**	**388**	**15**
COD, mg/L	**450**	**45**	**1295**	**35**	**400**	**180**	**422**	**188**
NH_4 – N mg/L	**23**	**8.0**	**28**	**2.4**	**16.6**	**14.4**	**29.6**	**3.2**
NO_3 – N mg/L	**1.2**	**3.4**	**3.4**	**6.8**	**2.0**	**4.0**	**6.0**	**8.0**
Total coliform, cfu/100 ml	**5800**	**1800**	**5600**	**2200**	**4700**	**1600**	**6200**	**1200**

See footnotes of Table 1

Evaluation of the quality of wastewaters under study for irrigation purposes

Water quality from the agricultural point of view is determined through determination and/or calculations of parameters relevant in relation to the maintenance of soil physical, chemical and biological properties at levels quite enough to keep soil productivity and at the same time protect soil against deterioration and pollution especially with heavy metals. Therefore, water quality is assessed through determining the degree of acidity or alkalinity (pH), electrical conductivity (EC), residual sodium carbonate (RSC) and sodium adsorption ratio (SAR) **(Ayers and Wescot 1994 and Glover, 1996)**. However, **Jenson and Zahng (2013)** reported that the two most important measures for determining irrigation water quality are: a) the total amount of dissolved salts in water b) the amount of (Na^+) in water compared to (Ca^{2+} + Mg^{2+}).

Hydrogen ion activity (pH)

Since the normal pH value ranges from 6.5 to 8.4 **(Ayers and Westcot 1994)**, all the investigated waste waters whether treated or untreated are considered suitable for agricultural irrigation from this point of view, where their EC values ranged from 7.35- 7.88 dSm^{-1}.

Salinity hazardous

The most influential water quality guideline on crop productivity is the water salinity hazard as measured by electrical conductivity (EC). The primary effect of high EC water on crop productivity is inability of the plant to compete with ions in the soil solution for water (physiological drought). The higher the EC, the less water is available to plants, even though the soil may appear wet.

Values of soil salinity as expressed in EC values presented in Table 1 ranged as mentioned before from 0.74 to 0.99 dSm^{-1} i.e. within the range 0.75 – 2.25 dSm^{-1}, which means that these waters are classified as C3 which refers to high salinity water that cannot be used in most cases without special precautions and only plants which tolerate salinity can be grown and irrigated with such waters **(USDA, 1954)**. At the same time, these waters are within the range 0.7 to 3 dSm^{-1} which indicates that there is slight to moderate degree of restriction on use of these waters for irrigation according to **Ayers and Westcot (1994)**. However, this type of water requires good management and favorable drainage conditions because salinity problem will develop if leaching requirements were not fulfilled. Furthermore, adequate drainage is required **(USDA, 1954)**.

Sodium hazards

Values of SAR presented in Table 4 are all below 10. Therefore, most of these waters are considered of low degree of restriction and satisfactory for all crops according to **USDA (1954)**. However, when taking EC values of these waters with their corresponding SAR ones (SAR = 0-3 and EC > 0.7 dSm^{-1}), these waters can be considered of no degree of restriction on use of these waters for irrigation of sensitive crops and there will no potential problem for infiltration due to use of this waters **(Ayers and Westcot, 1994)**. A parameter termed Adj-RNa which adjusts the Ca^{2+} concentration of the irrigation water to the expected equilibrium values and includes the effects of CO_3^{2-}, HCO_3^- and EC upon the Ca^{2+} present in the applied water.

The Adj RNa was determined using the equation:

$$Adj\, RNa = \frac{Na^+}{\sqrt{\frac{Ca_x^{2+} + Mg^{2+}}{2}}}$$

Where Na^+ = sodium concentration in the irrigation water reported in $mmolcL^{-1}$

Ca_x^{2+} = a modified Ca^{2+} concentration value in $mmolcL^{-1}$expected to remain in near surface soil water following irrigation with water of a given HCO_3^- / Ca^{2+} ratio and EC available from the standard tables (**Ayer and Westcot, 1994)**. Mg^{2+} = magnesium concentration in the irrigation water reported in $mmolcL^{-1}$

The Adj-RNa values of investigated wastewaters ranged from 2.09 to 5.56. These adjRNa values indicate that all the investigated wastewater samples whether before treatment or after treatment are considered suitable for irrigation purposes. High sodium content can cause deflocculating (break down) of soil aggregates; severely reduce soil aeration and water infiltration and percolation. In other words, soil permeability is reduced by irrigation with water high in sodium **(Rao, 2006).** It is therefore, the best measure of a water likely effect on soil permeability is the waters SAR considered together with its EC.

By plotting SAR values (Table 4) and corresponding EC ones (Table 1) of the investigated wastewaters on the classification diagram proposed by the **USDA (1954)**, it was found that all the investigated wastewaters (untreated or treated) are considered of high salinity (0.75 – 2.25 dSm^{-1}) and low sodicity (SAR< 10) i.e. C3-S1, this type of water cannot be used on soils with restricted drainage. Even with adequate drainage, special managements are required and high salt tolerant plants are recommended (USDA, 1954)

Table 4. Calculated parameters for judging quality of wastewaters for irrigation purposes.

Location		SAR	Adj RNa	RSC	Mg ratio
L1	**Inlet**	**6.97**	**5.56**	**-3.8**	**54.54**
	Oulet	**6.72**	**5.23**	**-3.8**	**50.00**
L2	**Inlet**	**6.11**	**5.15**	**-3.8**	**26.08**
	Oulet	**5.75**	**4.68**	**-4.2**	**45.83**
L3	**Inlet**	**5.09**	**3.67**	**-2.6**	**38.88**
	Oulet	**4.46**	**3.50**	**-2.4**	**31.25**
L4	**Inlet**	**2.24**	**2.63**	**- 0.97**	**32.49**
	Oulet	**1.84**	**2.09**	**- 1.96**	**26.30**

See footnotes of Table 1

Residual sodium carbonate (RSC).

The concept of residual sodium carbonate (RSC) measures the excess of carbonate and bicarbonate ions (CO_3^{2-} + HCO_3^-) over the divalent calcium and magnesium ions (Ca^{2+} + Mg^{2+}). **Eaton (1950)** pointed out that if irrigation water has appreciable bicarbonate, calcium and magnesium, carbonate will precipitate when the concentration of the soil solution is increased through evapotranspiration.

Data presented in Table 4 reveal that values of RSC ranged at the inlets of the investigated wastewaters treatment plants from - 0.97 mmolcL^{-1} at the inlets of El-Berka treatment plant to -3.8 mmolcL^{-1} at the inlets of Arab Abo-Saed and El-Gabl El-Asfer treatment plants. On the other hand, the RSC values at the corresponding outlets varied from -1.96 mmolcL^{-1} at the outlet of El-Berka treatment plant to -4.2 mmolcL^{-1} at the outlet of El-Gabl El-Asfer treatment plant.

The potential for sodium hazardous that increases as RSC increases, and much of calcium and sometimes the magnesium are precipitated out of solution when water is applied to the soil (Glover, 1996). According to USDA (1954) and Johnsen and Zhang (2013), residual sodium carbonate levels less than 1.25 mmolcL-1 are considered safe. Therefore, the investigated wastewaters can be considered safe according to their RSC values. Abbas (2013) demonstrated that when RSC is high in water, clay particles of soil swells or undergoes dispersion and drastically reduces soil infiltration.

Quality regading other soluble constituents (Miscellaneous)

There are other soluble constituents which may be considered in assessing quality of irrigation water. The most important of these are chloride, magnesium, boron and some trace elements (Ayers and Westcot, 1994).

Chloride (Cl-) hazards

Chloride ions have no harmful effect on physical properties of soil and are not adsorbed to any appreciable extent on soil colloids; hence they are not included in many water quality classifications. However, they may have adverse effect on plant growth, especially salinity – sensitive plants.

Chloride content of the investigated water samples ranged from 2.7 to 10.mmolcL-1 at inlets of the investigated wastewater treatments corresponding to a range of 3.6 to 12 mmolcL-1 at the outlets. It is worthy to indicate that Cl- concentrations at the outlets were generally higher than the corresponding ones at the inlets. This finding is due to chlorination process occurred as a means of wastewaters treatment in the investigated wastewater treatments plants. The concentration of Cl- at inlet of

El-Berka treatment plants is less than 4 mmolcL-1, so this water can be used for surface irrigation of sensitive plants and can be considered, as irrigation water of no problem from this point of view according to Ayers and Westcot (1994). However, all the other wastewater samples are classified according to the Cl- specific effect as water of increasing problem except for the treated wastewater at the outlet of Arab Abo-Saed whose concentration exceeded 10 and hence is considered of severe degree of restriction on use for surface irrigation according to Ayers and Westcot (1994).

On the other hand, all the investigated waste waters are considered according to their Cl- content as waters of slight to moderate or even severe degree of restrication on use for sprinkler irrigation. One exception is the waste water of El-Berka inlet which is considered of no degree of restriction on use for sprinkler irrigation of sensitive crops.

Magnesium (Mg2+) hazards

If Mg^{2+} concentrations increases at the expense of Ca^{2+} concentrations, Mg^{2+} might replaces Ca^{2+} on the soil complex, thus physical properties of soils would impaired. The magnesium ratio (Mg ratio) is taken as a measure of magnesium hazards as stated by **FAO (1973)** according to the following equation:

$$Mg\ \ ratio = \frac{Mg^{2+}\ concentration\ in\ water\ in\ mmolcL^{-1}}{(Ca^{2+} + Mg^{2+})} X100$$

The harmful effect of Mg^{2+} on soil physical properties (dispersion of soil particles) occurs when such a ratio exceed 50 % in the waters used for irrigation i.e. when Mg^{2+} occurs in water in concentration exceeding that of Ca^{2+}. Data presented in Table 4 show that no harmful or hazardous effect is expected upon using all the investigated wastewaters whether untreated or treated (except for those of Arab Abo-Saed) for irrigation purposes.

Boron hazards

Although B is a constituent of practically all natural waters and it is essential for plant growth, yet is exceedingly toxic at concentrations only slightly above optimum. There are several classifications according to boron toxicity among them **FAO classification (1973), Gupta classification (1979) and Ayers and Westcot (1976). FAO classification (1973)** consists of three classes in accordance with boron tolerance of crops 1) Water of 0.33 to 1.25 mgB L^{-1} may be used for boron sensitive crops, 2) Water of 0.67 to 2.25 mgB L^{-1} may be used for semi-tolerant crops and 3) water of 1 to 3.75 mgB L^{-1} may be used for boron tolerant crops. **Gupta (1979)** classified water into 5 classes i.e. normal water (B < 3 mg L^{-1}), low boron water (B: 3 – 4 mg L^{-1}), medium boron water (B: 4-5 mg L^{-1}), high boron water (B: 5-10 mg L^{-1}) and very high boron water (B: > 10 mg L^{-1}). **Ayers and Westcot (1976)** in their tri-classes FAO system considered 3 classes i.e. 1) No problems (B: < 0.75 mg L^{-1}), 2) Increasing problems (B: 0.75 – 2.0 mg L^{-1}) and 3) Severe problems (B: > 2.0 mg L^{-1}). According to all these three boron classification systems, all the investigated wastewaters contained very minute concentrations of boron (208 µg L^{-1} i.e. < 0.3 mg L^{-1} as a maximum value, see Table 2 and therefore, theses wastewaters can be used safely for agricultural irrigation purposes without any restriction.

Biological oxygen demand (BOD_5)

Tan (1994) reported that a BOD_5 value of 1 mg L^{-1} means that 1 mg L^{-1} of oxygen was consumed in the decomposition process during 5-days incubation period. This indicates that only a small amount of organic pollutants was present, hence the water being analyzed is of high quality. On the other hand, BOD_5 values > 5 in an analysis suggest that the water contains high amounts of organic contaminants. The BOD_5 values of the investigated wastewaters in this research work exceed obviously 5 mg L^{-1}, accordingly it can be deduced that these waste waters contain high amounts of organic contaminants, or are waters of low quality **(Stevenson, 1986)**. So, with few exceptions, the investigated wastewaters, especially the untreated ones at the inlets of the studied treatment plants, displayed high values of BOD_5.

Total NO_3 – N

Since as shown in Table 3, NO_3- N content varied from as low as 1.2 mg L^{-1} to only 8 mg L^{-1} as a highest content, the degree of restriction on use of these wastewaters for the irrigation purposes according to the guidelines of **Ayer and Westcot (1994)** proposed ranges from non to slightly moderate.

Total coliform

To protect public health, **WHO (1989)** guidelines recommended no more than one thousand fecal coliform / 100 mL for unrestricted irrigation. Therefore, concentrations of total coliform of the investigated wastewaters presented in Table 3 illustrate that there will be different degrees of restriction on usage of these waters for irrigation.

Heavy metal hazards

The recommended maximum concentrations of Cd, Ni and Pb are 0.01, 0.2 and 0.5 mg L^{-1} corresponding to 10, 200 and 500 µgL^{-1} respectively, which are far higher than the concentrations of these metals ions in the investigated wastewaters **(National Academy of Science and National Academy of Engineering , 1972).** Since the aforementioned maximum recommended concentrations were set because of concern for long term build up of trace elements in the soil and for protection of the agricultural resource of irreversible damage under normal irrigation practices, the concentration of Pb, Cd and Ni in the investigated wastewaters are not expected to cause build up that might limit future crop production or utilization of the product.

Effect of irrigation with waste waters on soil contents of hazardous metal ions and boron

Date presented in Table 5 and Figure 3 illustrate the implications of irrigating soils with the investigated wastewaters. Values of DTPA-extractable Cd ranged from 0.106 to 0.254 mg kg^{-1}. The corresponding values of Ni ranged from 0.498 to 1.5 mg kg^{-1} whereas those of Pb ranged from 92 to145 mg kg^{-1}. Therefore, these metal ions can be arranged according to their contents in soil in the following descending order: Pb > Ni > Cd. Such a sequence characterized distribution of the toxic metal ions in all investigated soils.

Table 5. Effect of irrigation with wastewaters on soil contents of hazardous metal ions and boron .

Location	Concentration mg kg^{-1}			
	Cd	Ni	Pb	B
L1	0.106	0.498	107	0.176
L2	0.254	1.47	92	0.250
L3	0.164	0.895	145	0.580
L4	0.250	1.50	98	0.200

See footnotes Table 1

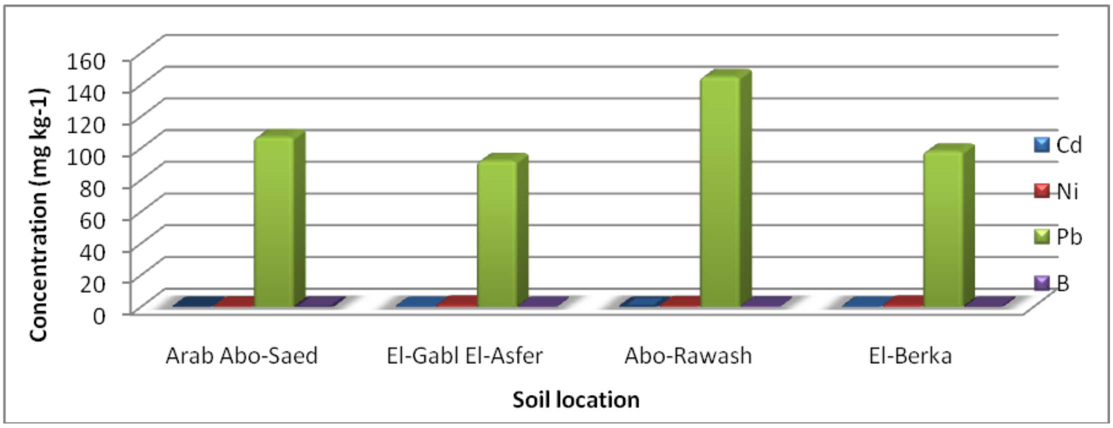


Fig. 3: Soil contents of hazardous ions and boron.

As a matter of fact the concentrations of the aforementioned metal ions reflect, to a great extent, their corresponding concentrations in the wastewaters used for irrigating the considered soils. Meanwhile, concentrations of these metal ions are within the permissible limits of waters used for agricultural purposes. Boron content in soils ranged from 0.176 mg kg^{-1} in Arab Abo-Saed soil to 0.58 mg kg^{-1} soil in Abo-Rawash soil. Boron contents of El-Gabl El-Asfer and El-Berka come in between (0.25 and 0.20 mg kg^{-1} soil, respectively. Therefore, content of B in all the investigated soils are within the permissible limits and no hazardous effects are expected on plants grown on these soils.

Conclusions

All the investigated wastewaters (untreated or treated) are considered of high salinity (0.75 – 2.25 dSm^{-1}) and low sodicity (SAR < 10) i.e. C3-S1, this type of water cannot be used on soils with restricted drainage. Special managements are required and high salt tolerant plants are recommended. All the investigated heavy metals i.e. Cd, Ni and Pb were found in either not detectable concentrations or very minute ones i.e. within the permissible limits for waters used for agricultural purposes. Also, boron content is very small and no hazardous effects are expected due to use of these waters for irrigation. On the other hand, more attention should be paid towards reducing the microbial contamination of waste waters to protect public health.

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تقييم جودة مياه الصرف الصحى لأغراض الرى.

حسن حمزة عباس – هبة شوقى راشد – ضياء الدين أمين الزياتى

قسم الأراضى والمياه – كلية الزراعة بمشتهر – جامعة بنها – مصر.

من أهم المشاكل التى تواجة عملية الزراعة بمصر هى الحاجة الى توفير كمية كبيرة من المياه لأستخدامها فى عملية الرى وعلى ذلك تعتبر مياه الصرف الصحى المعالجة من احدى الوسائل الواعدة لتوفير كمية كبيرة من المياه لأستخدامها بالزراعة وخصوصا بعد بناء سد النهضة باسيوبيا والذى سوف يترتب عليه قلة حصة المياه الواردة لمصر والذى بدوره سوف يؤثر فى كمية المياه المتاحة للزراعة. وعلى الرغم من ذلك فانه بالاهمية بمكان إجراء تقييم دورى لمياه الصرف التى سوف تستخدم فى الزراعة حيث انها تحتوى على العديد من الملوثات المختلفة والتى لابد من التخلص منها قبل إعادة إستخدامها. وعلى ذلك تهدف الدراسة الحالية لدراسة الخصائص المختلفة لكلا من مياه المدخل والمخرج النهائى لعدد من محطات المعالجة (عرب ابو ساعد – الجبل الأصفر – أبورواش – البركة). وقد تم متابعة عملية المعالجة والتأكد من صلاحية المياه الخارجة من المحطة بعد المعالجة من خلال إجراء التحاليل المعملية التالية (الاس الهيدروجينى – التوصيل الكهربائى – المواد العالقة الكلية – الايونات الذائبة – النيتروجين الأمونيومى – النيتروجين النتراتى – الاكسجين الممتص حيويا والاكسجين المستهلك كيميائيا – بالإضافة الى عنصر البورون ومجموعة من العناصر الثقيلة (الرصاص – النيكل – الكادميوم) وقد تم التركيز على المحتوى البكتيرى للمياه من خلال تعيين البكتريا القولونية الكلية. وقد أوضحت النتائج المتحصل عليها ان جميع العينات التى تم تحليلها تحتوى على نسبة ملوحة عالية بالإضافة الى قلة تركيز الصوديوم بالإضافة الى تركيزات قليلة لا تكاد تذكر من العناصر الثقيلة و أيون البورون. وعلى ذلك فإنه من الممكن إستخدام مياه المخرج النهائى المعالجة فى أغراض الرى مع الأخذ فى الاعتبار كلا من الراشح من المياه وكذلك أنواع المحاصيل التى سوف تروى بها. وعلى الرغم من هذه النتائج الإيجابية فان كمية البكتريا القولونية الكلية كانت أعلى من الحدود المسموح بها وعلى ذلك لابد من معالجة المياه بطرق ذات كفاءة عالية للمحافظة على صحة الأنسان من الملوثات البكتيرية.