Appraisal of Blending Water Quality for Agricultural Reuse: Laboratory Bench-top Experiments

Lubna A. Ibrahim[1] and H.A.A. El Gammal[2]

[1] Center Lab. for Environmental Quality Monitoring,, National Water Research Center, Cairo, Egypt.
[2] National Water Research Center, Cairo, Egypt
E-mail:elgammalhussein@gmail.com

Abstract: A mixing evaluation is a systematic approach addressing the impacts of changing water source on water quality. This paper examines water quality of Umoum Drain (UD), Western Delta region, Egypt. It discusses a blending methodology with Nubaria Canal (NC) water for predicting its suitability for reuse in irrigation. Water samples were collected for one year, from October 2012 to September 2013, from UD and NC. In lab, water from both drain and canal was mixed using ratios of 1:1, 1:2, 1:3, 1:4 and 1:5, respectively, to determine the suitable ratio for irrigation. By measuring Physical and chemical parameters, regarding to FAO guidelines, it was noticed severe restrictions on reusing water from UD for irrigation of susceptible crops, while no serious restrictions were noticed regarding to NC water. Furthermore, for blended water samples, it was noticed slight to moderate restrictions. Fecal coliform(FC*)* bacteria compared to World Health Organization (WHO) guidelines expected possible health hazards from pathogens in case of irrigating crops eaten raw or uncooked for UD, NC and blended water samples except sample with ratio 1:4 and 1:5, respectively. Based on physical, chemical and bacteriological results obtained, water quality index analysis classified UD as poor drainage water while NC as fair surface water. Also, blended water samples are classified as marginal surface water for samples prepared form drainage fresh water with ratio of 1:1, 1:2, and 1:3, in addition to a ratio of 1:4 and 1:5 for the fair surface water. The study recommended to blend the drainage water with fresh water using the ratio of 1:4 or 1:5, respectively, to be used in irrigation of eaten raw crops.
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Key Wards: Blended water, Laboratory, Bench top, Nubaria canal, Umoum drain, Egypt.

1. Introduction

Released Nile water from the High Aswan Dam (HAD) for Egypt is 55.5 BCM/year. Over the past two decades, the basic policy of the Ministry of Water Resources and Irrigation allows demands to increase more or less laissez-fair basis, resulting in a dramatic increasing irrigation density and extension. However, due to the increase in population, industrialization, and urbanization this policy is no longer adequate and reserved of water. The recycling of agricultural drainage water has become the core of Egypt's water management (APRP, 1998). Wastewater reuse involves the beneficial use of treated wastewater in applications such as irrigation, industrial cooling or as process water. Because of limited water resources, the use of highly treated wastewater effluent, now discharged to the environment from municipal or industrial wastewater treatment plants, is receiving more attention as an alternative source of water. Priority shall be given to agricultural reuse of treated effluent for unrestricted irrigation (MWRI, 2013). Blending of treated wastewater with fresh water shall be made to improve its quality where it is possible. Crops to be irrigated by the treated effluent or blend thereof with freshwater resources shall be selected to suit the irrigation water, the soil type and chemistry, and the economics of the reuse operations.

The problem that has been faced in this research is the exposure of 120 thousand acres, which have been reclaimed from Mariut sector, to desertification in absence of water. One of the proposed solution was the restarting of the mixing Mariut pump station, which located at 85.5 km right bank of Nubaria Canal (NC), to feed the Canal with water from Umoum Drain (UD). Mariut had been stopped working from about 12 years ago due to existence of Borg Al-Arab water treatment plant inlet downstream the blending point. The restarting of this pump station offers about 1 million m^3/day of non-conventional water to NC. This agrees with the ambitious development plans for reclaiming about 1.0 million acres initiated by the decision makers in 2014. Blending of different water sources, untreated, may exacerbate the problem.

Effects of mixing or blending different water types have been considered over a number of years. A procedure for optimizing the blending water from many sources to minimize the salinity of water used to irrigate crops should be described. Booth *et al.,* 1998, concluded in their study that a selection of a blending based on a target source water parameter, such as alkalinity, results in more consistent water than does blending based on a quantity alone. AWWA, 2001, provided a detailed background of the water quality impacts from blending multiple water types.

The aim of this research is to assess the physical, chemical, biochemical and bacteriological characteristics of UD and NC water to propose the best ratio for blending and to evaluate the successful conditions for irrigation. In addition to the determination of the effect of commingling or blending upon the saturation index and prevent changes in corrosivity or precipitation potential.

2. Material and Methods

Study Area

Nubaria canal (NC) and Umoum drain (UD) are the largest canal and drain in the Western Delta region of Egypt (Fig. 1). NC is a second order irrigation canal diverted from El-Beheiry Rayah, which serves El Nubaria and El Nasr General Irrigation Directories (El Gammal and Ali, 2008). The canal length is 100 km and serves a command area of 1,150 acres. At present, the average discharge of the NC is 23 million m^3/day. About 2,126 MCM/day of drainage water are added to NC at different locations, which is about 8.67% of its maximum discharge. The water of NC is used to provide drinking water to portions of the El-Beheira and Alexandria governorates, as well as cities of Borg El-Arab and El-Nubaria. Further, it provides a source for drinking water for tourist villages along the north coast and Marsa Matruh Governorate.

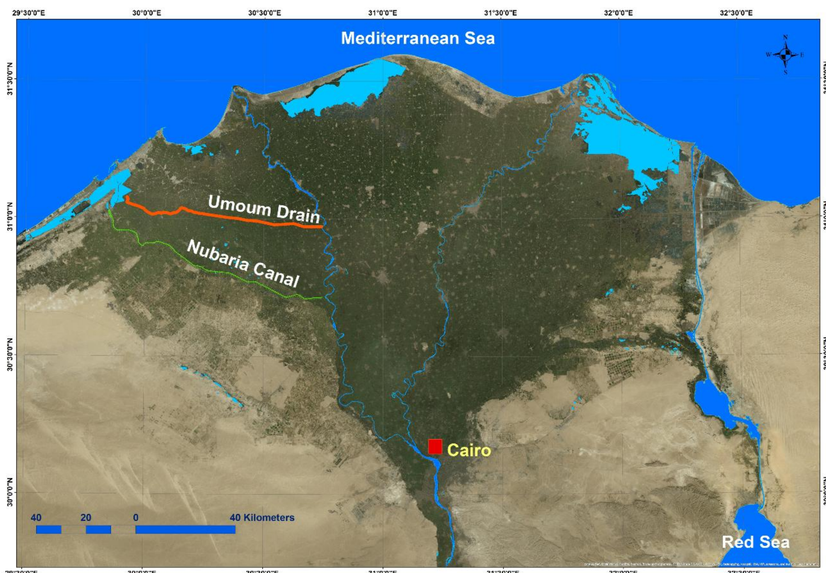

Fig.1: Study Area

UD catchment area covers approximately 422,820 acres with a travel length 41 km. It receives more than one billion cubic meters per years (1BCM/y) of agricultural drainage water. Moreover, the drain receives both raw and treated wastewater from several defined and undefined sources.

Water Sampling and Analyses

Water samples have been collected in triplicates from the studied site in various containers specialized to suit the nature of tested parameters according to Standard Methods for Examination of Water and Wastewater (APHA and *et al.,* 2012). The selection of water samples were collected periodically six times from October 2012 through September 2013 from UD and NC to assess the possibility of reusing their water in irrigation, as shown in Figure 2. For laboratory analyses, water samples have been collected in stopper polyethylene plastic bottles. All collected and examined samples, for physical, chemical and bacteriological have been stored in an iced cooler box and delivered immediately to the laboratory for analyses. For blending water, samples have been collected from UD and NC in stopper polyethylene plastic bottles of 10 liters for each sample. After blending, water samples have been prepared and preserved according to the standard methods for analyses.

All reagents were used for analytical grade and deionized water was used for all the prepared reagent solutions. The plastic bottles were cleaned by soaking in 10% HNO_3 and the procedural blanks of standard solutions were prepared under clean laboratory environment. Recovery studies for the trace elements have been analyzed using inductively coupled plasma-mass spectrometry (ICP-MS) ranged between 99 and 102%. Stock standard solutions of aluminum, cadmium, chromium, cobalt, copper, iron, manganese, lead, nickel, vanadium, and zinc, have been obtained from Merck in concentrations of 1000 mg/L. All media used in bacteriological analyses have been obtained in a dehydrated form, Difco USA.

Collected water samples from the feeding pump stations at UD and NC have been mixed with ratios of 1:1, 1:2, 1:3, 1:4 and 1:5, respectively, Table 1. Samples were mixed in two liters glass beaker for five minutes using a magnetic stirrer and blending ratios and volumes were only a suggestion and other variations might be carried out as long as the final volume (requirement for analyses). Mixed water samples analyzed for their physical, chemical, biochemical and bacteriological analyses.

Table 1: Blending volumes and ratios for the collected samples from UD and NC.

Sample code	Volume of drain water (mL)	Volume of canal water (mL)	Ratio
B1	**1000.0**	**1000.0**	**1:1**
B2	**666.6**	**1333.4**	**1:2**
B3	**500.0**	**1500.0**	**1:3**
B4	**400.0**	**1600.0**	**1:4**
B5	**333.3**	**1666.7**	**1:5**

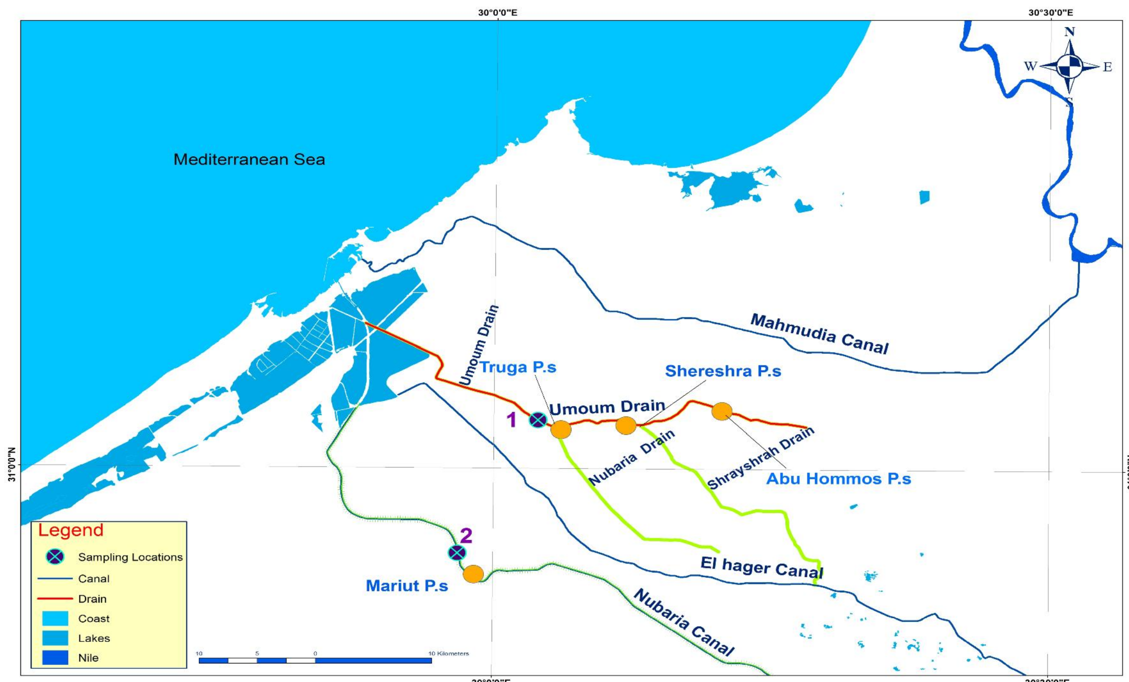

Figure 2: Map of the studied area showing the sampling location.

Physical and chemical analyses: The physical and chemical parameters have been analyzed according to standard methods for testing fresh water and wastewater. For chemical analysis, field parameters include temperature, hydrogen ion (pH), dissolved oxygen (DO), and electrical conductivity (EC) were measured in situ using the multi-probe system and model Hydralab-Surveyor. For major cations and trace elements(HM), the samples were filtered by filtration system through membrane filter of pore size 0.45 µ and acidified with nitric acid to pH <2 before analyses.

In lab, pH and EC were measured at 25 C^{o} using Info Lab meters. Also, turbidity (Turb) was measured by Turbidity meter with calibration solutions of 0.1, 15, and 100 NTU. Carbonate and bicarbonate were detected by titration method using 0.02 N H_2SO_4. Concentrations of ammonia in water were determined using the calorimetric techniques with formation of phenate. Total dissolved solids (TDS) were determined by weighing the solid residue obtained by evaporating a measured volume of filtered water sample to dryness at 103-105 ^{o}C. Total suspended salt for filtrated water samples was determined gravimetrically at 105 ^{o}C. Major anions; chloride (Cl^-), sulfate (SO_4^{2-}), nitrate (NO_3^-), and phosphate (PO_4^{3-}) were measured using Ion Chromatography (IC). Major cations; calcium (Ca^{2+}), potassium (K^+), magnesium (Mg^{2+}), and sodium (Na^+) were measured by inductively coupled plasma-optical emission spectrometry (ICP-OES). Dissolved and total (digested samples) HM (Cd, Cu, Fe, Mn and Zn) were measured in water by using the inductively coupled plasma-mass spectrometry (ICP-MS).

Biochemical analyses: Biological Oxygen Demand (BOD) was measured by respirometric method with measuring range 0-4000 mg/L at 20 ºC incubation in a thermostatic incubator chamber for 5 days.

Bacteriological Analyses: All collected and blended water samples were examined within 6 hours after collection and preparation. Membrane filter technique was applied using a filtration system completed with stainless steel autoclavable manifold and oil-free" vacuum/pressure pump for counting fecal coliforms. The samples were filtered through sterile, surface girded membrane of pore size of 0.45 µm with diameter of 47 mm. The data were recorded as Colony Forming Unit (CFU/100 ml) using the following equation:

$$\frac{Colonies}{100ml} = \frac{Counted\ colonies}{ml\ of\ sample\ filtered} \times 100$$

The data is analyzed using statistical package for social science (SPSS) . The data is analyzed and presented as mean ± standard error.

3. Result and Discussion

At the farm level, treated wastewater should have acceptable quality to be used in crops irrigation , irrigation water should not cause harmful effects to plants, soils, human and animal health, and water resources (surface and groundwater). The relevant properties of a water source for use in irrigation can be subdivided into physical, chemical, and biochemical as well as micro-biological properties. The physical, chemical, and biochemical parameters are temperature (C^o), pH, EC, turbidity, TSS, DO, HM (B, Fe, Mn, Zn, Cu, and Cd), Biochemical Oxygen Demand (BOD) and *Faecal coliforms (FC)*.

Physical and chemical parameters impacts

Impacts of most relevant physical and chemical irrigation water parameters on plants, soils, groundwater and human health are summarized from Figure (3) to Figure (13). A general evaluation of each parameter is given as follows:

The temperature of irrigation water beyond the critical limit has adverse effect on crops. Irrigation water should have a temperature between 4 to 30 Co (FAO, 1985). Temperature of all sample locations ranged from 23 to 26 Co this indicates that water in NC and UD is suitable for irrigation and there is no thermal pollution.

Irrigation water with pH values outside the normal range (6.5 - 8.5) may cause a nutritional imbalance or may contain a toxic ion and dissolution of organic matter, where low pH may cause accelerated irrigation system corrosion where they occur (Alobaidy *et al.,* 2010). The mean pH values are 7.69±0.16, 7.82±0.14, 7.66±0.06, 7.70±0.04, 7.68±0.06, 7.68±0.05, and 7.71±0.14 for NC, UD, B1, B2, B3, B4 and B5, respectively, Figure 3. It means that all studied and blended water samples are within the permissible limit for irrigation water and have no significant negative impact on plants or soils, on nutrient availability for plants, and on irrigation equipment (which could corrode, or which may develop a scale or precipitation of carbonates).

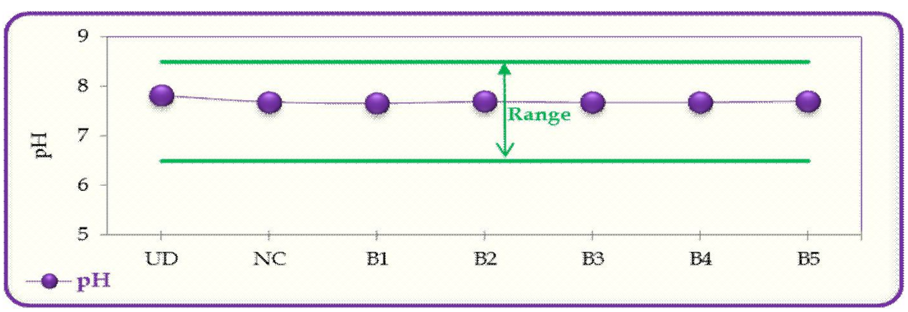

Figure 3: Mean pH values (n=18) for collected and blended water samples

The bicarbonate and carbonate content of irrigation water deserve careful evaluation. Substantial bicarbonate levels in irrigation water may increase soil pH, and in combination with carbonate they may affect soil permeability. The bicarbonate ion may combine with calcium and magnesium and precipitate as calcium carbonate and magnesium carbonate. This precipitation increases sodium adsorption ratio (SAR) in the soil solution. Bicarbonate ion in drain, canal, and blended waters ranges from 1.5 to 8.5 which indicate that this water has slight to moderate restriction, Figure (4). Bicarbonate hazard of water could be express as Residual Sodium Carbonate (RSC), calculated as expressed in the following equation. Concentrations of ions are expressed in meq/L as:

$$RSC = (HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})$$

According to Richards (1954), water with an RSC value of lower than 1.25 meq/L is safe for irrigation, water with an RSC ranges between 1.25 and 2.5 meq/L is marginal, and water with an RSC more than 2.5 meq/L is probably not suitable for irrigation. As a result, the present study showed that all the analyzed samples have RSC less than zero which indicate as good for irrigation purposes, Table (2).

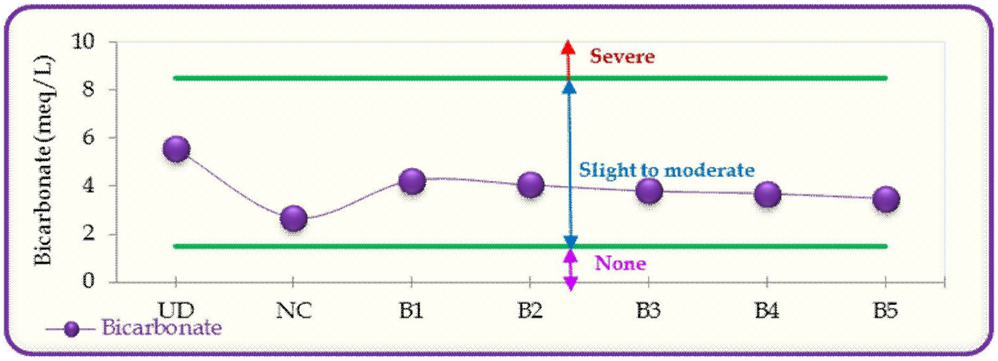

Figure 4: Mean concentration of bicarbonate ions (n=18) for collected and blended water samples

Table 2: Blending volumes and ratios for the collected samples from UD and NC.

Sample co	RSC	Sample	RSC	Sample	RSC	Code	RSC
UD	-7.08	B1	-2.97	B3	-1.34	B5	-1.03
NC	-0.46	B2	-1.79	B4	-0.97	-	-

As shown in Figure (5), mean values for EC are 0.61±0.07, 3.37±0.27, 1.768±0.25, 1.393±0.15, 1.203±0.11, 1.072±0.06, and 1.005±0.06 mS/cm for NC, UD, B1, B2, B3, B4 and B5, respectively. According to FAO, 1992, plants are classified into 3 categories; sensitive (EC < 0.7mS/cm), salt medium tolerant (EC between 0.7 and 3.0 mS/cm), and salt tolerant plants (EC > 3.0 mS/cm). This means the following:

1) UD water is suitable for salt tolerant plants , such as olive, pepper, cucumber, cauliflower, lettuce, watermelon, cabbage and grapes

2) NC water is suitable for salt sensitive plants, such as almond, carrots, apple and onion; and Cowpea.

3) Blended water from B1 to B5 is suitable for moderately tolerant plants, such as Broadbean, Maize, Flax, Millet foxtail, Groundnut peanut, Rice paddy, Sugarcane, Sunflower, alfalfa, Burnet, Clover alsike, Clover Berseem, Clover ladino, Clover red, clover strawberry, and clover white Dutch.

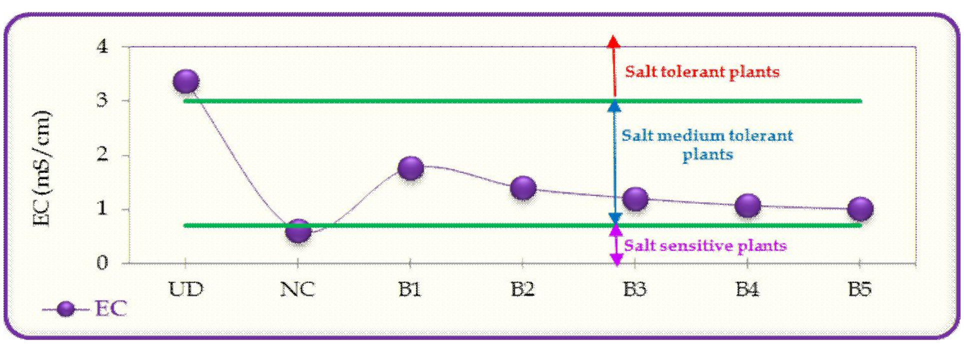

Figure 5: Mean EC values (n=18) for collected and blended water samples.

High values of suspended solids (SS) may reduce the permeability of the surface soil layer or/and may cause clogging of micro irrigation systems. Normal suspension in irrigation water can only have physical and may be chemical impacts on irrigation systems, such as pipes, canals, pumps …etc. If using sprinkler irrigation, SS will precipitate on leaves and fruits, which will lead to low quality productivity. According to the Harivandi (1999), SS level below 50 mg/L is safe for drip irrigation systems while values above 100 mg/L will cause plugging. As a result, Figure (6) showed that SS values ranged from 5 to 7.1 mg/L which are safe for irrigation systems. In addition, the SS ranging of all studied water samples was less than the recommended value for agricultural reuse for food crops commercially processed and non-food crops.

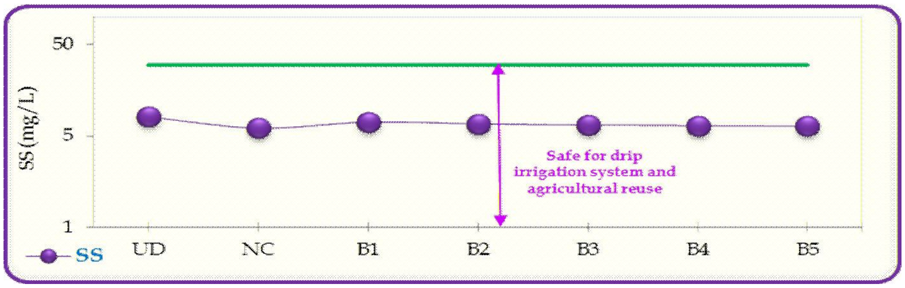

Figure 6: Mean SS values (n=18) for collected and blended water samples.

As shown in Figure (7), The total dissolved salts (TDS) in UD is 1815.5 mg/L, while in NC is 392.6 mg/L. UD water can be reused for irrigations but with slight to moderate effect on crop production, and NC is safe for irrigation. Also, Soluble salts in blended water are 1136, 891, 771, 693 and 645 mg/L for B1, B2, B3, B4 and B5, respectively. So that, Samples B1, B2, B3, B4 and B5 are mariginal (slight to moderate restriction must be taken) for irrigation depending on recommended water quality criteria for irrigation (FAO, 1985).

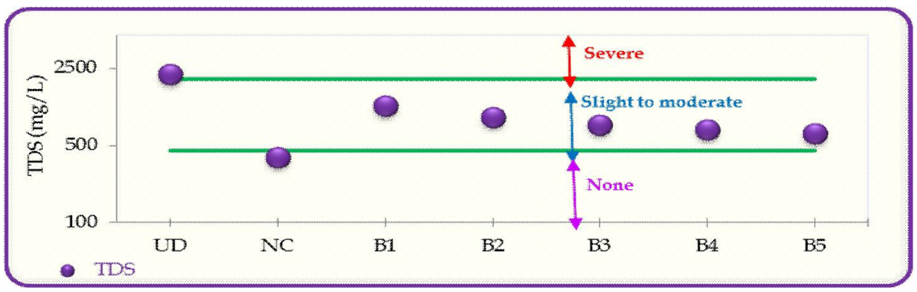

Figure 7: Mean TDS values (n=18) for collected and blended water samples.

According to Khodapanah *et al.,* 2009, calcium and magnesium ions are essential for plant growth but they may associated with soil aggregation and friability and high concentration of calcium and magnesium in irrigation water can increase soil pH, resulting in reducing availability of phosphorous. In addition, water contains calcium and magnesium concentration higher than 10 meq/L (200 mg/L) can't be used in agriculture. Ca and Mg concentrations in all studied samples are less than the recommended value 5 meq/L. With respect to Potassium (K^+), it is usually used as fertilizer. Only at very high concentrations (> 80 mg/l), it reduces plant uptake of Ca. Results for all analyzed samples, K^+ concentration are less than the recommended value 2 meq/L, Figure (8).

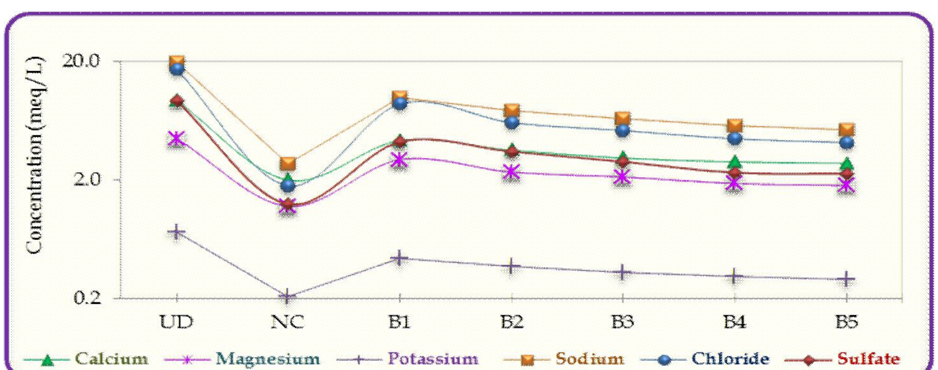

Figure 8: Mean concentration of Ca^{2+}, Mg^{2+}, K^+, Na^+, Cl^- and SO_4^{2-} (n=18) for collected and blended water.

Sodium and Chloride Hazard:

The analysis of Sodium "Na" and Chloride Hazard "Cl" are the major salinity parameters in irrigation water. Therefore, their concentrations are generally reflected in the EC values. Na and Cl in UD water are severe to use for irrigation, while for Nubaria canal (NC) water can be used without any restrictions. For blended water samples "Na" and "Cl" concentrations are in the range of slight to moderate restriction (5 to 9 meq/L for "Na" and 4 to 8 meq/L for "Cl"), Figure (8).

The SAR is the best indicator of sodium effect when irrigation water is applied to the soil. The high sodium content common to recycled water can cause deflocculation (breakdown) of soil clay particles, severely reducing soil aeration and water infiltration and percolation. When the SAR value is less than 6, there is no problem are to be expected for soils or plants. When SAR ranges from 6 to 9, it may cause some problems to soils such as decreasing soil permeability. When SAR is higher than 9, it may cause clogging of soils, FAO, 1985. Results for all analyzed samples showed that SAR values for UD, NC, B1, B2, B3, B4, and B5 are 6.77, 2.15, 5.14, 4.43, 4.08, 3.73 and 3.52, respectively. Blending of UD and NC resulted in the decrease of SAR values for irrigation water. The values of SAR for mixed water are in the range of 3 to 6, while EC values higher than 1200 µS/cm indicated that we can use this water without any restriction according to FAO Guidelines.

The effect of sodium ions in the irrigation water in reducing the infiltration rate and soil permeability depends on the total salt concentration, as shown in Table (3). Comparing SAR values for studied water samples with values in the table, the water sample collected from NC has slight reduction, while UD and blended water samples have no reduction.

Table 3: Potential infiltration problem due to sodium in irrigation water

Salinity levels of irrigation water dS/m	No reduction *SAR*	Slight reduction *SAR*	Medium reduction *SAR*	Severe reduction *SAR*
EC_w = 0.7	<1	1-5	5-11	>11
EC_w = 0.7-3.0	<10	10-15	15-23	>23
EC_w = 3.06-6.0	<25	>25	No effect	No effect
EC_w = 6.0-14.0	<35	>35	No effect	No effect
EC_w = >14.0	No effect	No effect	No effect	No effect

Source: Based on Rhoades, Oster and Schroer.

Soluble Sodium Percentage (SSP): The sodium in irrigation waters is also expressed as percent sodium or soluble sodium percentage SSP and can be determined using the following equation:

$$SSP = \frac{Na^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \times 100$$

Where all ionic concentrations are expressed in meq/l. Irrigation water with SSP greater than 60% may result in Na accumulation and possibly a deterioration of soil structure, infiltration, aeration and reducing soil permeability. The value for SSP of collected and mixed water samples was 57, 44, 56, 55, 54, 53and 52 for UD, NC, B1, B2, B3, B4 and B5, respectively, indicating good irrigation water quality.

Wilcox presented an irrigation classification diagram based on the specific conductance and the percent of sodium. The diagram is divided into divisions based on the relation between the total concentration of anions or cations (meq/L) and the concentration of sodium in water, Figure 9. The distribution of the plotted points indicated that water from UD is doubtful to unsuitable for irrigation, while samples from B2 to B5 and NC are good to permissible and B1 water sample is permissible to doubtful for irrigation.

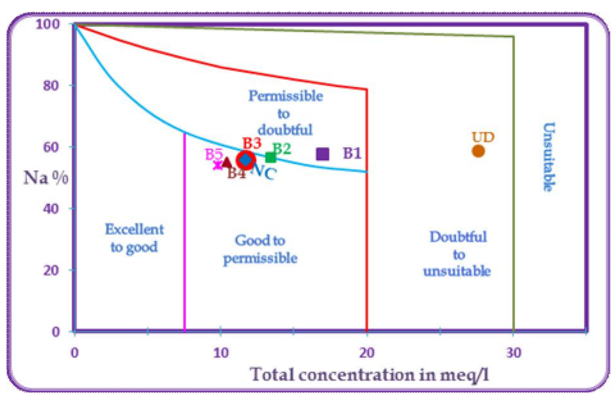

Figure 9: Wilcox diagram for collected and blended water samples

Exchangeable Sodium Percentage (ESP):

ESP value for irrigation water can be calculated from the following empirical relationship (Richards, 1954):

$$ESP = \frac{100(-0.0126 + 0.01475 \times SAR)}{1 + (-0.0126 + 0.01475 \times SAR)}$$

The value of ESP for UD, B1 and B2 are in the range 6 to 9 which is causing problems with soil infiltration and permeability, while for NC, B3, B4 and B5 are less than 5, which is a desired value for irrigation.

Sulphate (SO_4^{2-}):

The concentrations in all the studied samples are less than the recommend value 20 meq/L, (Ayers and Westcot, 1985). So, these water samples don't have major effects on plants or soils and can be used in sprinkler irrigation, So they don't have any damage to leaves or fruits.

Ammonia (NH_3) in NC ranges from 0.3 to 0.7 mg/l with a mean value 0.4±0.2 mg/L. Most of the time the average value of NH_3 is close to the local standards (0.5 mg/l) except only one collected sample which can be attributed to the activity of aquatic organisms. After blending with different ratio, NH_3 was 0.6, 1.1, 0.7, 0.5 and 0.5 mg/L for B1, B2, B3, B4 and B5, respectively. It is noted that samples B4 and B5 are close to the standard 0.5 mg/L and are suitable for irrigation. Nitrates of the UD ranges from 10.44 to 20 mg/l with average 15.17 mg/L, while NO_3- values in the blended water were 8.43, 6.47, 5.51, 6.84, 4.73 mg/L B1, B2, B3, B4 and B5, respectively, which are significantly below the local standards (45 mg/l), Fig 10. Before mixing, the total phosphorous of the UD water varies from 0.18 to 0.26 mg/l with a mean value 0.23±0.04. The TP values of the mixed irrigation water B1, B2, B3, B4 and B5 are 0.13, 0.10, 0.08, 0.1 and 0.08 mg/L, respectively, which is less than the local standards (1.0 mg/l).

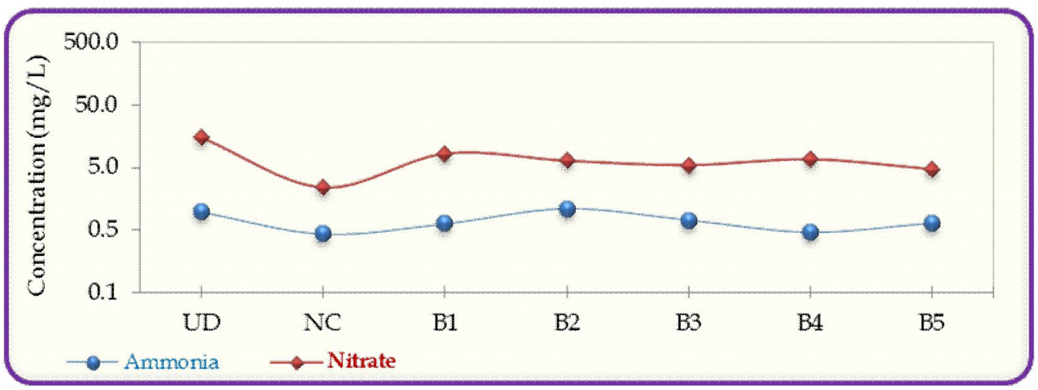

Figure 10: Mean conentration for nitrate and ammonia (n=18) for collected and blended water samples.

BOD ranges from 3 to 6 mg/L in NC and 4 to 7 mg/L in UD. The mean BOD values of blending water were 2, 2.32, 2, 2.67 and 3 for B1, B2, B3, B4 and B5 samples, respectively, Figure 11. All samples were less than the recommended limit for agricultural reuse for food crops not commercially processed (10 mg/L).

Boron (B): Levels of boron as low as 1 to 2 mg/L in irrigation water can cause leaf burn on ornamental plants, but turfgrasses can often tolerate levels as high as 10 mg/L (Harivandi, 1999). The results indicated that both blended and unblended water contain boron less than 1 mg/L, which is suitable for irrigation.

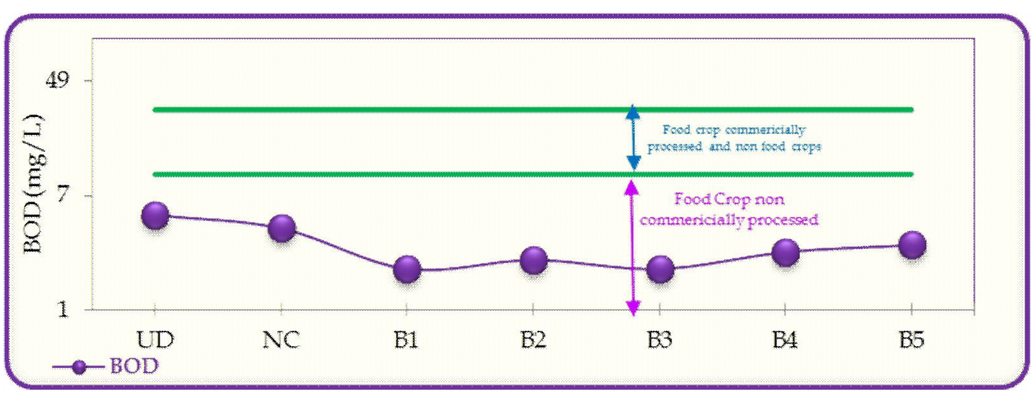

Figure 11: Mean BOD values (n=18) for collected and blended water samples.

Figure 12 shows the concentrations of HM in UD, NC, and the blended water. The mean value of Ferrous (Fe) for UD was 1.5 mg/L and that for NC was 0.739 mg/L. The Content of Fe in mixed water samples was 0.827, 0.482, 0.472, 0.438 and 0.219 mg/L for B1, B2, B3, B4 and B5, respectively, which are less than maximum permissible Fe in irrigation water, 5.0 mg/L (CCME, 2005) indicating that all the studied samples are suitable for irrigation. The manganese (Mn) content of UD varied from 0.17 to 0.29 mg/L, while for NC was 0.026 mg/L. The Mn in blended water is 0.126, 0.091, 0.077, 0.07 and 0.063 mg/L and these values are less than the maximum allowable limit of Mn in irrigation water is 0.20 mg/L. Zinc (Zn) water samples values are less than the recommended value 5 mg/l for irrigation water. The Copper (Cu) concentration in UD is higher the recommended limit 0.2 mg/L in contrast to NC which has a mean value 0.032 mg/L. The Cu values in the blended water are 0.20, 0.19, 0.19, 0.18 and 0.18 mg/L for B1, B2, B3, B4 and B5, respectively, and are less than the local standards (1 mg/l) .

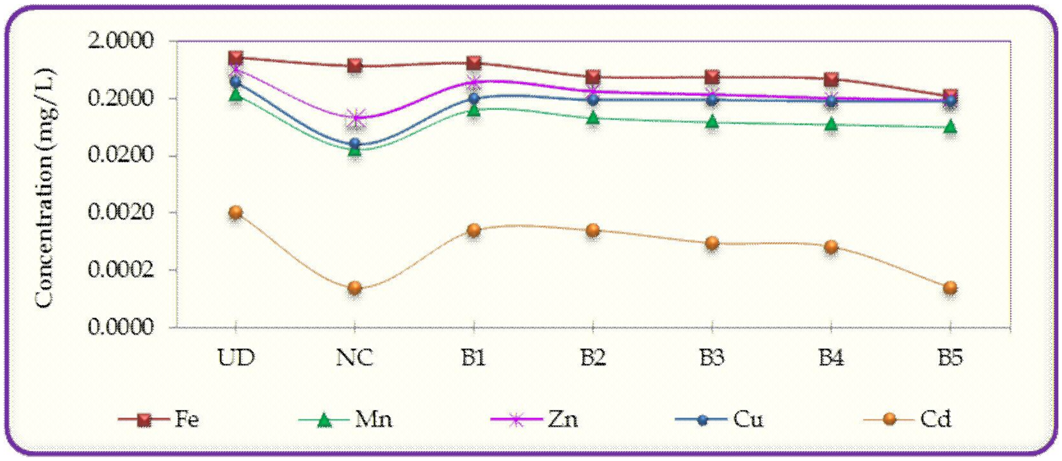

Figure 12: Mean Heavy metals(HM) values (n=18) for collected and blended water samples.

Pathogens

Irrigation water with partially treated wastewater may contain pathogens that might be hazardous to farm staff and the public, if certain protection practices are not applied. A limit of maximum of 1000 Fecal Coliforms or Escherichia Coli as geometric mean number per 100 mL is recommended (WHO, 2006). Figure 13, showed that UD, NC, B1, B2, B3 and B4 samples are suitable for irrigation for uneaten, cereal and industrial crops, pasture and trees. However, health associated risk could be expected on using for irrigation of crops that are eaten raw or uncooked. Restrictions and precautions should be taken seriously, these might include discontinue irrigation two weeks before crop harvesting to allow a sufficient inactivation of potential pathogens and parasites. Moreover, spray or sprinkler irrigation should be avoided (Blumenthal *et al.,* 2000). Sample B5 contains fecal coliform less 1000 CFU/ml referring to its suitability for irrigation of crops likely to be eaten uncooked, sports fields and public parks.

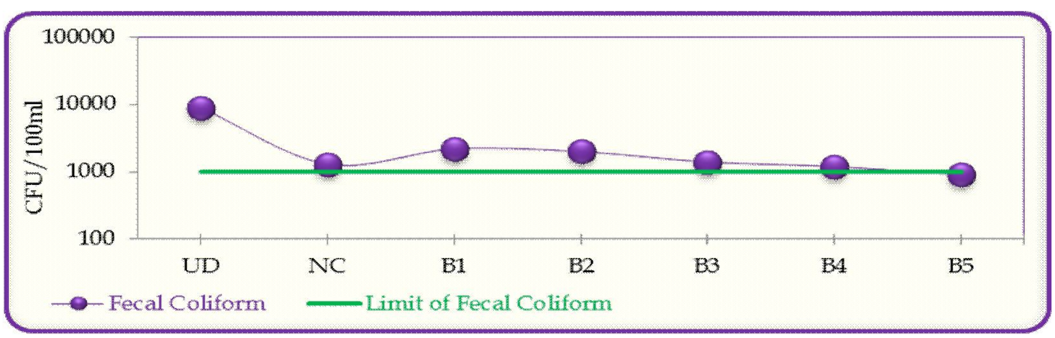

Figure 13: Mean *Fecal Coliform* (n=18) for collected and blended water samples.

Saturation Indices

The Langelier Saturation Index (LSI) is a method of ascertaining the aggressive or scaling condition of water. pH, conductivity, total dissolved solids, alkalinity and temperature have been used for LSI calculation. Whereas, actual pH of the water is compared to the theoretical one (pHs) based on the chemical analysis. The Saturation Index (SI) is given by:-

LSI= pH- pHs

Where, pH_S can be determined by using the equation:

$pHs = (pK_2 - pK_s) + pCa + pALK$

Where, pK_2 is negative logarithm of the ionization constant of the bicarbonate ion HCO_3^-, pK_s is the negative logarithm of the solubility product of $CaCO_3$, pCa is the negative logarithm of calcium concentration and pAlk is the negative logarithm of the total alkalinity measured for the water being evaluated.

The LSI values for UD, NC, B1, B2, B3, B4 and B5 samples are 0.6,-0.23,0.14,0.12,0.026, -0.0007,and -0.003 ,respectively. This indicates that water from UD is scale forming and not corrosive, while water from NC is slightly corrosive. The results showed some decrease in corrosive tendency due to water blending.

Water Quality Index (WQI) Index

A water quality index is a tool to summarize large amounts of water quality data into simple terms (e.g. good or fair) for reporting to decision makers and the public in a consistent manner. It evaluates and ranks the quality of water bodies for various beneficial uses of water, such as habitat for aquatic life, agricultural irrigation and livestock water, recreation and aesthetics, and drinking water supplies. In December 2007 a beta version of the Egyptian Water Quality Index (EWQI), based on the Canadian Council of Ministers of the Environment (CCME) Water Quality Index (WQI) was developed, (Khan *et al.,* 2008). The detailed formulation of the WQI is described in the Canadian Water Quality Index 1.0 – Technical Report (CCME, 2001).

The results of (WQI) showed that UD water quality was classified as poor drainage water (i.e. water quality is almost always threatened or impaired; conditions usually depart natural or desirable levels) with WQI = 44. The NC water quality was classified as fair surface water (i.e. water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels) with WQI = 67. The blended water samples were classified as marginal surface water (i.e. water quality is frequently threatened or impaired; conditions often depart from natural desirable levels) for B1, B2 and B3 with WQI= 58, 60 and 64 and fair surface water for B4 and B5 with WQI = 67 and 71.

Conclusions and Recommendations

Predicting properties of blended waters can provide insight into water reuse in a system, and provide solutions for minimizing problems by blending streams. pH changes are not always vary consistently, although the blend value is still in the individual water values. The TDS, EC, hardness, cations, anions and to some extent turbidity of the blends vary in a linear manner with blend ratio, so they readily predictable. Variation in *Fecal coliform* does not show linearity as well as BOD concentration with blend composition. There is a slight to moderate restriction on reusing from NC and mixed water samples. Blending is a useful method to minimize corrosivity. The present research concluded that UD water quality is classified as poor drainage water, while NC as fair surface water. The blended water samples are considered as marginal surface water of 1:1, 1:2 and 1:3 and fair surface water for 1:4 and 1:5 for samples ratio (UD:NC). Evident from the previous results that the best mixing ratio of UD to NC was 1:4 and 1:5 taking into account the nature of soil and its degree of permeability and type of plant that can be grown. It is worthwhile to mention that continuous irrigation with blended water may lead to accumulation of salts, nutrients, and/or heavy metals beyond crop tolerance. So, leaching ratio should be commissioned. It is recommended to have a field study to assure the suitability of the blended water for irrigation under different soils and crop conditions.

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