Investigating the Water Quality of El-Salam Canalto Reconnoiter the Possibility of Implementing Itfor Irrigation Purposes

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Abstract: This study investigates the water quality of El-Salam Canal with the objective of reconnoitering the possibility of implementing it for irrigation purposes. Water samples were collected from eight sites during the Over the period (Feb.- Sept. 2010). The samples were analyzed chemically and the obtained values were compared to the Food and Agricultural Organization (FAO), Water Environment Federation (WEF) and the World Health Organization (WHO). It was found that the water is capable to be used for irrigation purposes in the light of the pH, COD, BOD and heavy metals values but the values of EC, TDS, alkalinity, Na, Cl and fecal coliform might moderately restrict its implementation. It was concluded that receiving the water from Bahr Hadous drain with its inorganic salts and organic loads (i.e. due to the disposal of sewage, urban and agricultural runoff as well as industrial wastewater), increases the concentration of most of measured parameters of El-Salam Canal. The study, thus, emphasized the urgent need of formulating effective strategies to treat the drainage water sources before mixing them with the Nile water. The study also recommended introducing on-site treatment technologies to drainage water in order to improve the water quality along El-Salam Canal. Studying the impact of changing the drainage water – freshwater mixing ratios at Bahr Hadous pump station in addition to predicting the best ratio, might improve the water quality.
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1. Introduction

In Egypt, the population density, within the inhabited part, is 1500 capita\km^2. Worldwide, this is considered to be one of the highest densities. This necessitates the redistribution of the population over a larger area. In order to accomplish this, new lands should be reclaimed; new industrial regions should be created; new cities (provided with the necessary infrastructure) ought to be constructed. This might create new job opportunities and food.

In Egypt, irrigation water is scarce with the continuous demand increase of agricultural, domestic and industrial purposes. To face this increasing demand, the water supply is supplemented by the reuse of agricultural drainage water. This does not satisfy the water quality standards (defined for irrigation purposes) **[1]**.

Egypt has been practicing drainage water reuse since the 1930s. This was adapted through an official drainage water reuse policy in the late 1970s. The Government of Egypt is undertaking major projects to divert considerable amounts of drainage water to newly reclaimed areas. One of the projects, diverting drainage water to new reclaimed areas, started in 1985.

The Egyptian Government envisages the reclamation of 620,000 feddans of desert situated along the Mediterranean Coast of Sinai (220,000 feddans of which lie west of Suez Canal and about 400,000 feddans east of Suez Canal) by diverting considerable amounts of agricultural drainage water after blending it with Nile water **[2]**.

El Salam Project plays a great role in the economic and social development of Egypt as it creates agro-industrial opportunities of employment, builds new communities able to attract people out of the overpopulation areas in the Nile Delta, and contributes in increasing food production so as increasing the possibility of diversification of crop production **[3]**.

The total inhabitant of Sinai is 3.2 million capita and the aim is to create job opportunities to be 800,000 by year 2017. This might consume a total investment of 20 billion USD **[4]**.

Since 1992, joint governmental and international development agencies cooperated to provide environmental impact assessment to the canal project. Among the major positive impacts of the canal project were reclaiming desert soils and developing new agro-ecological habitats, improving socio-economic conditions for the native and introduced settlers and fixing sand dunes. However, the expected negative impacts included pressure increase the on the natural ecosystems, build up of soil salinity leading to soil degradation, and seepage increase of contaminated groundwater into aquifers so as Bardawil Lake **[5]**.

The irrigation scheme of the canal is based on the concept of partial reuse of agricultural drainage water. El-Salam Canal has been designed to supply the irrigation water as a mixture of Nile water and agricultural drainage water **[6]**. The mixing ratio of both waters is 1:1. This ratio was determined to reach an amount of total dissolved solids (TDS) of not more than 1000-1200 mg/l to be suitable for the cultivated crops **[7]**.

Study Objectives

The aim of the present work is to explore the water quality of El-Salam canal resulting from using the mixed Nile water and agricultural drainage water (ADW) for irrigation purposes and define the most effective mixing points that needs improvement in order to reach the standard water quality for irrigation along the canal.

2. Materials and Methods

Choosing The Study Area

After reviewing the literature and setting the study objectives, a study area was chosen. This area begins at the intake of the canal at Km 219 on the right bank of Damietta Branch of the Nile and ends at 3 km upstream of the Faraskour Dam.

The total length of the canal is 252.750 km and comprises two main parts.

- Part 1: it is 89.750 km long, lies to the west of the Suez Canal and is named El-Salam Canal.
- Part 2: it is 163.000 km long; is located to the east of the Suez Canal and is named El Sheikh Gabr Canal.

Both parts are connected through El-Salam Siphon (i.e. 770 m long inverted siphon under the Suez Canal.El-Salam Canal water is a mixture of 2.11 billion m^3/year of the Nile fresh water from the Damietta branch mixed with 1.905 billion m^3/year of the drainage water from Bahr Hadous and 0.435 billion m^3/year of El Serw dranage water. So the total quantity of water is nearly 4.45 billion m^3/year with a ratio of Nile water to drainage water approximately 1:1.

The Problem of The Study Area

The mixing ratio 1:1 was planned in order to reach an amount of total dissolved solids (TDS) not more than 1000-1200 mg/l to be suitable for cultivated crops However, due to the rationalization of irrigation water use policy in the Eastern Delta region, an increase in the official and unofficial drainage reuse along Bahr Hadous drain was detected to feed canal tail ends, either by gravity or through lifting by pumps of 1 m^3/sec capacity. This significantly affected the volume of water allocated for El-Salam Canal, figure (1).

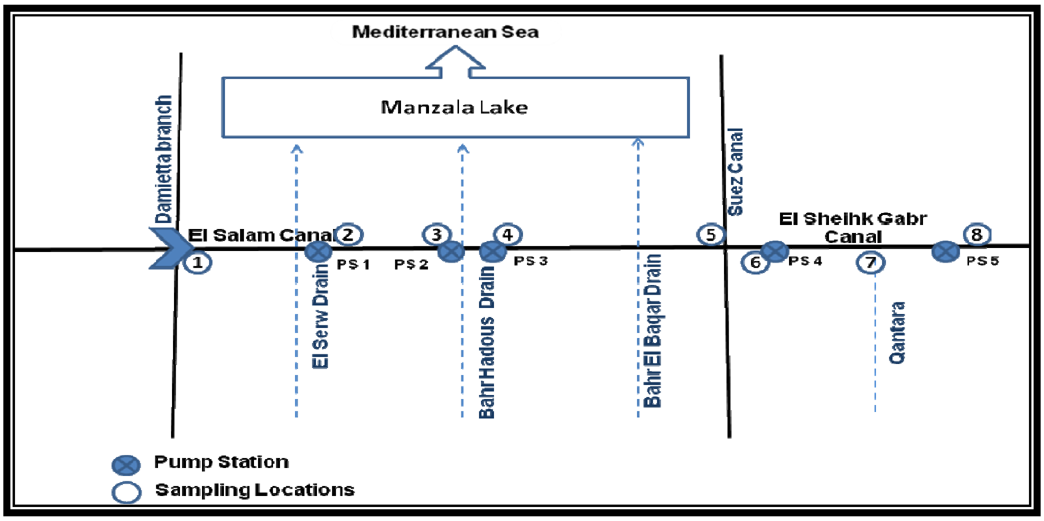

Fig. 1: Schematic diagram for water sampling locations

Water Sampling:

Samples were collected in February through September 2010. 64 samples were collected from eight sites, figure (1). All the collected samples were stored in an iced cooler box and delivered immediately to the Central Laboratory for Environmental Quality Monitoring, National Water Research Center "CLEQM-NWRC". The samples were chemically and bacteriologically analyzed.

Sampling procedures as well as analytical methods for both chemical and bacteriological determinations were carried out according to Standard Methods for Examination of Water and Wastewater, **[8]**.

Chemical Analyses:

Field parameters including temperature, pH and Electrical Conductivity (EC) were measured in situ using the multi-probe system, model Hydralab-Surveyor. In laboratory, Total Dissolved Solids (TDS) were determined by the gravimetric method. Biochemical Oxygen Demand (BOD) was detected using ORION BOD fast respirometry system model 890, Chemical Oxygen Demand (COD) was measured by COD spectrophotometer TR/2010 model 690 with COD reactor HACH. Major anions were determined using Ion Chromatography (IC) model DX-500, while carbonate and bicarbonate were detected by titration method using 0.02 N H_2SO_4. Major cations and trace metals were measured using the Inductively Coupled Plasma–Mass Spectrometry (ICP - MS), Perkin Elmer Sciex, ELAN 9000.

Bacteriological Analyses:

All collected samples were examined within 6 hours after collection. For counting total coliforms and fecal coliforms, the membrane filter technique was applied using a filtration system completed with stainless steel autoclavable manifold and oil-free "MILLIPORE" vacuum/pressure pump. Water samples were filtered through sterile, surface girded "SARTORIOUS" membrane of pore size 0.45 µm and diameter 47 mm, according to standard methods No. 9222B, 9222 D and 9230 C on M- Endo Agar LES, M-FC agar, and M-Enterococcus agar medium, respectively. All media used were obtained in a dehydrated form, Difco USA. Results were recorded as Colony Forming Unit (CFU/100 ml) using the following equation:

$$Colonies / 100\ ml = \frac{counted\ \ colonies}{ml\ of\ sample\ filtered} \times 100 \qquad (1)$$

3. Results and Discussions

The samples were analyzed chemically and bacteriologically. After analyzing the samples, they were evaluated and compared to international guidelines.

Chemical Analyses:

Chemical evaluation of water samples were compared to Food and Agriculture Organization (FAO) guidelines for irrigation **[9]** and Water Environment Federation (WEF) **[10]** and are given on Table (1) and Figure (2).

Results given in Table (1) and illustrated by figure (2) show that the measured temperature range between 18.4 – 25.8 ^{0}C and is governed by seasonal variations.

The pH values range between 7.35and 8.20 which fall within the permissible limits (6.5 – 8.5).

Table (1): Average values of physicochemical parameters during winter and summer seasons

Parameters	Season	Sampling Locations							
		Canal Input	P.S.#1	P.S.#2	P.S.#3	El-Sahara	P.S.#4	Qantara	P.S.#5
Temp. (^{0}C)	Winter	18.4	19.0	19.3	19.2	19.6	19.8	19.7	19.5
	Summer	25.5	25.4	25.1	25.6	25.8	25.7	25.6	25.2
pH	Winter	7.56	7.60	7.72	7.58	7.68	7.48	7.45	7.35
	Summer	7.72	7.58	7.68	7.48	7.88	7.81	7.77	8.20
Alk. (meq/l)	Winter	3.11	3.21	3.28	5.51	4.56	4.07	3.23	3.25
	Summer	2.88	3.06	3.23	5.26	4.02	3.77	4.10	3.82
EC (mmhos/cm)	Winter	0.62	0.72	0.72	2.75	1.66	1.37	1.12	0.87
	Summer	0.62	0.95	0.75	1.94	1.37	1.31	1.48	1.73
TDS (mg/l)	Winter	330	461	460	1900	1062	876	687	554
	Summer	317	443	432	1562	874	839	945	1105
BOD (mg/l)	Winter	19	24	16	40	23	32	28	20
	Summer	15	23	15	38	21	18	21	14
COD (mg/l)	Winter	23	37	24	59	32	42	35	26
	Summer	21	29	21	53	29	25	32	20

Alkalinity ranges between 2.53 and 5.51 meq/l indicating the highest value, for the sample collected from the canal in front of PS # 3 in winter season. This might be attributed to the untreated domestic wastewater from Bahr Hadous drain. By comparing those values to FAO guidelines it was found that all values fall between 1.5 and 8.5 meq/l indicating slight to moderate restriction to its use for irrigation purposes. EC concentrations range between 0.454 and 2.750 dS/m while TDS concentrations range between 291 and 1900 mg/l showing highest value for the sample collected from the canal in front of PS # 3 in winter season where TDS values along El Salam canal are less than 500 mg/l where it increases to reach 1900 mg/l in winter after mixing with Bahr Hadous drain. This might be attributed to inorganic salts that dissolve in water originating from sewage, urban and agricultural runoff as well as industrial wastewater. By comparing those values to FAO guidelines, it was obvious that there is no restriction on using it.

This could be applied for El-Salam Canal water for irrigation before mixing with Bahr Hadous Drain (EC

<0.7 dS/m and TDS < 500 mg/l) while after mixing slight to moderate restriction should be imposed on using it for irrigation purposes. The values that should be applied are EC 0.7 – 3.0 dS/m and TDS 500 – 2000 mg/l.

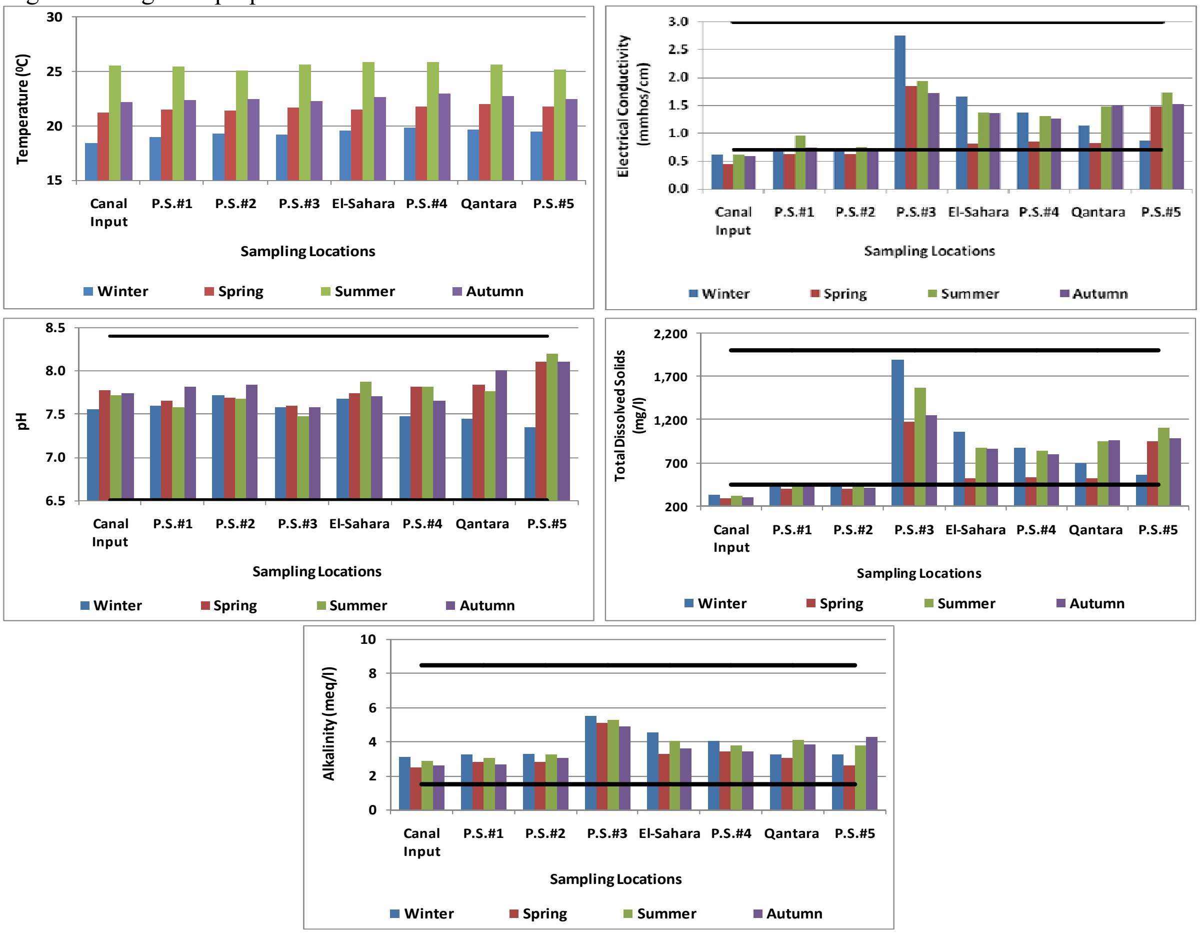

Fig. 2: Seasonal variation of some physicochemical parameters in different sampling locations

As shown in Table (1) and illustrated in figure (3) show that the BOD and COD values range between 3 – 40 and 5 -59 mg/l, respectively, where the maximum values were reached (i.e. for the sample collected from the canal in front of PS # 3 in winter). This might be attributed to the significant amounts of organic pollutants from domestic diffuse sources and fertilizers from Bahr Hadous drain **[11]**. However by comparing the BOD and COD values to the WEF permissible limits it is clear that both parameters are within the permissible values (i.e. 10 – 40 mg/l 75 – 80 mg/l for BOD and COD, respectively).

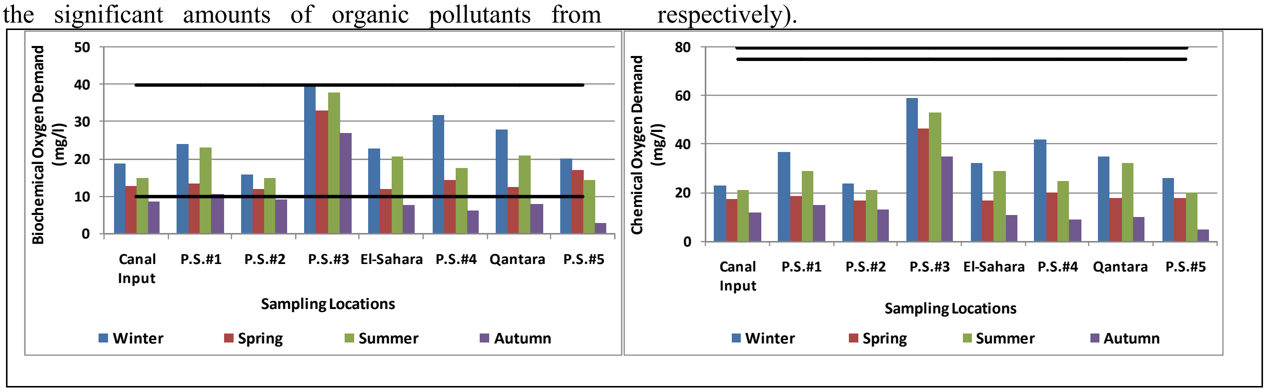

Fig. 3: Seasonal variation of BOD and COD in different sampling locations

Average values in winter and summer seasons for major cations and anions including calcium (Ca^{2+}), potasium (K^{+}), magnesium (Mg^{2+}), sodium (Na^{+}), chloride (Cl^{-}), phosphate (PO_4^{3-}) and sulphate (SO_4^{2-}) concentrations are listed in Table (2).

Table (2): Average values of cations and anions during winter and summer seasons

Parameters	Season	Sampling Locations							
		Canal Input	P.S.#1	P.S.#2	P.S.#3	El-Sahara	P.S.#4	Qantara	P.S.#5
Calcium (mg/l)	**Winter**	40	47	49	139	90	73	84	94
	Summer	40	47	49	139	90	73	84	94
Potassium (mg/l)	**Winter**	7.2	8.8	8.6	20.0	15.0	13.0	13.0	10.0
	Summer	6.9	8.1	8.9	17.0	11.0	12.0	13.0	13.0
Magnesium (mg/l)	**Winter**	15	19	18	56	31	24	15	20
	Summer	13	17	14	45	21	20	24	27
Sodium (meq/l)	**Winter**	2.15	3.21	3.31	14.00	9.46	8.00	5.16	4.17
	Summer	0.00	0.00	0.00	0.00	8.17	7.96	8.60	8.00
Chloride (meq/l)	**Winter**	1.68	3.19	3.05	12.00	8.99	7.54	5.42	4.06
	Summer	0.00	0.00	0.00	0.00	7.25	7.19	8.12	8.00
Phosphate (mg/l)	**Winter**	0.04	0.00	1.11	1.87	0.80	0.70	0.00	0.20
	Summer	0.03	0.00	0.07	1.05	0.60	0.26	0.00	0.00
Sulphate (mg/l)	**Winter**	41	52	66	286	145	110	98	146
	Summer	38	50	57	249	115	113	101	120

It was shown that Ca^{2+}, K^{+}, Mg^{2+} , Na^{+}, Cl^{-}, PO_4^{3-} and SO_4^{2-} concentrations ranged between 36 and 139 mg/ l, 7 and 20 mg/ l, 10 and 56 mg/ l, 0 and 14 meq/ l, 0 and 12 meq/ l, 0 and 1.87 mg/l and 29 and 286 mg/l respectively. Those concentrations could originate from agricultural runoff or as a result of natural distengrations **[12]**.

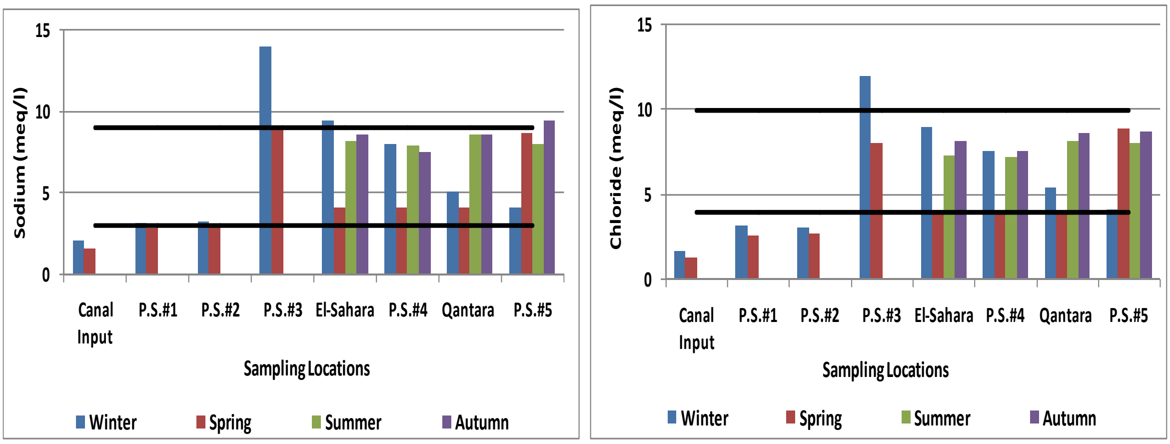

Fig. 4: Seasonal variation of sodium and chloride in different sampling locations

Figure (4) show that by comparing those values to FAO guidelines, it is obvious that there is no restriction on use will be applied for El-Salam canal water for irrigation before mixing with Bahr Hadous drain (<3.0 and <4.0 meq/l for sodium and chloride, respectively) while after mixing slight to moderate restriction on use should be applied (3 to 9 and 4 to10 meq/l for sodium and chloride, respectively).

Total concentrations of fourten trace metals (aluminum, arsenic, cadmium, cobalt, copper, nickel, lead, iron, zinc, manganese, chromium, vanadium, selenium and tin) were analyzed. Only five metals are listed in Table (3) as the rest where less than the instrument detection limit (0.001 mg/l for arsenic, cadmium, nickel, lead, zinc and selenium; 0.005 mg/l for aluminium, cobalt and tin). It can be seen that all the trace metals were below the FAO guidelines (i.e. 0.1 mg/l for vanadium and chromium, 0.2 mg/l for copper and manganese and 5.0 mg/l for iron).

Table (3): Average values of trace metals during winter and summer seasons

Parameters	Season	Sampling Locations							
		Canal Input	P.S.#1	P.S.#2	P.S.#3	El-Sahara	P.S.#4	Qantara	P.S.#5
Chromium (mg/l)	Winter	0.012	0.010	0.012	0.027	0.015	0.012	0.008	0.004
	Summer	0.009	0.013	0.014	0.015	0.017	0.009	0.010	0.016
Copper (mg/l)	Winter	<0.001	<0.001	<0.001	0.006	<0.001	0.004	<0.001	<0.001
	Summer	0.068	0.097	0.145	0.145	0.074	0.071	0.158	0.119
Iron (mg/l)	Winter	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
	Summer	0.061	0.084	0.087	0.139	0.129	0.123	0.082	<0.02
Manganese (mg/l)	Winter	<0.006	<0.006	<0.006	0.041	<0.006	<0.006	<0.006	<0.006
	Summer	0.014	0.021	0.026	0.049	0.037	0.020	0.033	0.018
Vanadium (mg/l)	Winter	<0.005	<0.005	0.005	0.016	0.008	0.006	<0.005	<0.005
	Summer	<0.005	<0.005	<0.005	0.007	0.005	<0.005	<0.005	<0.005

Bacteriological Analyses:

Bacteriological evaluation of water samples that were collected along El Salam Canal were recorded in CFU/100ml and are presented in Table (4).

The values in Table (4) declared that there is an obvious bacterial contamination in most of sampling locations. Among the two primary bacterial indicators, total coliforms, represented the higher count followed by fecal coliforms.

Table (4): Average values of bacterial indicators during winter and summer seasons

Parameters	Seasons	Sampling Locations							
		Canal Input	P.S.#1	P.S.#2	P.S.#3	El-Sahara	P.S.#4	Qantara	P.S.#5
Total coliform (CFU/100ml)	Winter	6416	11067	36667	78000	7467	7567	9800	3008
	Summer	1420	7462	7011	32100	3100	4600	2917	874
Fecal coliform (CFU/100ml)	Winter	514	891	11100	24578	1154	1089	1800	325
	Summer	120	521	824	17000	745	940	567	216

Values in table (4) showed that the total coliform and fecal coliform values range between 103 and 78,000 CFU/100 ml and 34 and 24,578 CFU/100 ml, respectively. Bacterial contamination recorded in this study could be attributed mostly to domestic sewage pollution as well as agricultural runoff **[13 & 14]**.

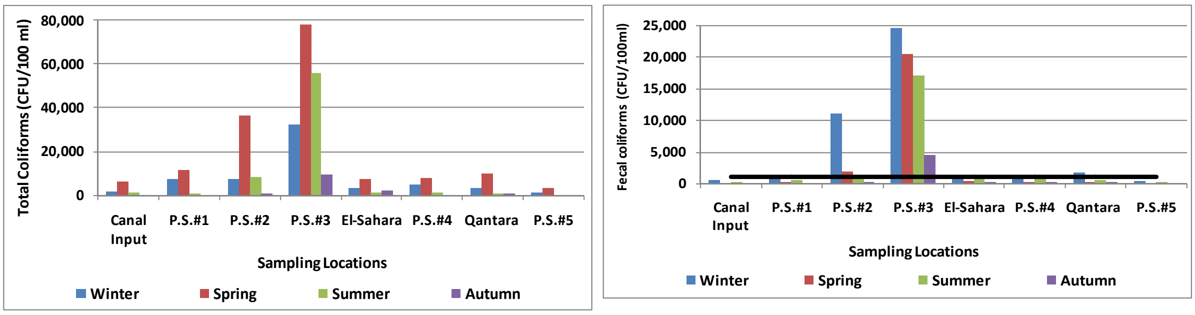

Fig. 5: Seasonal variation of bacteriological contaminants in different sampling locations

From Figure (5), it is evident that Bahr Hadous drain is the major contributor to the observed peak in CFUs recorded in El Salam Canal owing to its sewage nature.

It was also clear that as per the World Health Organization (WHO) recommended microbiological quality guidelines for wastewater reuse in agriculture **[15]**, El Salam Canal water could be used for irrigating crops likely to be eaten uncooked, sports fields, public parks (fecal coliform ≤ 1000) while after mixing with Bahr Hadous drain (PS # 3), it is suitable for irrigation of cereal, industrial as well as fodder crops 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 **[16]**.

Conclusion and Recommendations

Based on the present investigation, it was concluded that:

- The canal water is chemically acceptable for irrigation except in front of pump station # 3 which indicates the negative impact of mixing Bahr Hadous Drain on the water quality of the canal at this area.
- El-Salam Canal water is subjected to sewage and agricultural pollution which might increase the risk of spreading infections. It can be used for irrigating crops likely to be eaten uncooked, sports fields, public parks (fecal coliform $\leq$ 1000) while after mixing with Bahr Hadous Drain PS # 3, it is suitable for irrigation of cereal, industrial as well as fodder crops and trees. However, health associated risk could be expected on using for irrigation of crops that are eaten raw or uncooked.
- The main source of chemical and bacteriological pollution along El Salam Canal is Bahr Hadous drain. The current proposed mixing ratio of 1:1 between Bahr Hadous and El Salam Canal water might not be enough to reduce pollution to acceptable levels.

According to the study findings it is recommended to:

- Implement effective strategies for the treatment of the drainage water resources before mixing with the Nile water and introducing on-site treatment technologies of drainage water to help improve water quality along El-Salam canal.
- Promote studying the impact of changing the drainage water – freshwater mixing ratios at Bahr Hadous pump station, in addition to predicting the best ratio that improves the water quality.

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