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Research Article

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Effects of pollution on hydro-chemical and water quality assessment of the Ismailia Canal water, Egypt

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ABSTRACT

The major ions chemistry characterizations of the Ismailia Canal water were determined by the purpose of identifying the different geochemical processes and the suitability of the water resources for irrigation, drinking portability. Piper diagram detects that the surface canal water mixed with contaminated water where there is a general tendency towards no dominant cation water type and bicarbonates are the dominant ions in all the samples analyzed in the Ismailia Canal with a certain modification of the hydro-chemical types. This modification of the water is due to non points and points sources of pollution. Ca-Mg-Na-HCO_3 is the dominant hydro-chemical type of the Ismailia canal water in the study area. Calculated values of the sodium adsorption ratio (SAR), Sodium ratio (%Na), Magnesium ratio and residual sodium carbonate (RSC) show that all of the Ismailia Canal water is of acceptable irrigation quality limits. In conclusion, the canal water types had resulted from mixing of different types of different complex physic-chemical processes..

Key words: *Hydro-chemical, Water quality, Ismailia Canal, Pollution.*

INTRODUCTION

Ismailia Canal is considered as fresh water used for drinking, industrial and fishing purpose for about 12 million inhabitants in Egypt. Its discharge is 433.56 m^3 /sec. It supplies the water to the northern part of Cairo, Suez, Ismailia, and Port Said cities. The length of the canal is 128 km. Its dimensions average 18, 2.1 m width and depth respectively. On the two banks of the canal, there are several factories constructed. They discharge their wastes into the canal water, making change in the water quality of the canal[9]. The hydro-chemical characteristics of canal water estimate the value of agricultural, industrial and domestic water supplies. The kind and concentrations of the dissolved minerals estimate the suitability of water for each of its different uses.

MATERIALS AND METHODS

1.1 Water samples:

The present study was done during winter and spring seasons in 2014. Six stations were selected along Ismailia Canal extended from El-Mazallat area to Abu Zabal City. These stations are represented in Fig. 1. The locations of these stations are:

Station I: The binging of Ismailia Canal branched from River Nile at El Mazallat area
Station II: In front of Oil and Soap factory. Station III: In front of Iron and Steel production factory. Station IV: In front of Petroleum Company. Station V: Abu Zabal City. Station VI: Anshas City.

Water samples were collected in a plastic bottle, kept in an icebox then returned directly to the lab for analysis.

1.2 Field measurements:

Air, water temperatures, electrical conductivity and pH values were measured, using Hydro lab, Model “Multi 340I/SET”.

1.3 Laboratory analyses:

The following parameters were measured according to the methods of APHA (1998): total dissolved solids (TDS), dissolved oxygen (DO), chemical oxygen demand (COD), biological oxygen demand (BOD), nitrite (NO_2), nitrate (NO_3^-), ammonia (NH_3), sodium (Na^+), calcium (Ca^{2+}), potassium (K^+), sulfate (SO_4^{2-}), chloride (Cl^-), orthophosphate (PO_4^{2-}) and total phosphate (TP). The metal ions of Cu, Pb, Mn, Zn, Cd and Fe were measured using inductively coupled plasma optical emission spectrometer (ICP-OES).

RESULTS AND DISCUSSION

2.1 Major parameters concentrations

Many earlier studies have revealed the major parameters chemistry[4,5,11,15,25]. The major parameters chemistry of Ismailia Canal water is summarized in Table 1 showing the range and the mean values. The anions in Ismailia canal are found in order $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^-$ contributing to average concentrations of the six stations, 52.8, 21.9, 17.5 and 6.9% to the total anions in the winter, and 52.4, 20.17,18.2, 9.9 % in the spring. The Calcium (Ca^{2+}), Mg^{2+}, Na^+ and K^+ concentrations represent according to average to of the total cations are found in the order $Ca^{2+}>Mg^{2+}> Na^+>K^+$ in the winter, 31.2 , 41.8, 23.4 and 3.4 % and in the spring 33.4, 31.3, 30.4, 5.2 % in the same order. Measured pH of the analyzed samples varied from 7.9 to 8.3 and varied from 8 to 8.4 for the winter and spring seasons respectively, indicating the alkaline nature of the canal water. The electrical conductivity indicates the total material dissolved in water. It was determined ranges from 341 to 351 µS /cm and 382 to 440 µS /cm during the winter and spring respectively. The TDS in the canal water ranges from 175.4 to 216 mg l^{-1} in winter and 149.8 to 167.8 mg l^{-1}in the spring season. The study shows the concentration of potassium (K^+) seems low compared to other cations. The normal source of potassium (K^+) in water may be due to dissolution of minerals of igneous rocks[16].

2.2 Heavy metals

Heavy metal contamination is one of the major environmental concerns of the world due to the rapid progress of industry. Moreover, their natural occurrence, heavy metals may get into the ecological environment through anthropogenic activities. The variation in the concentrations of trace metals (Fe, Mn, Cu, Zn and Pb) in the winter and the spring seasons in the canal water in the study area is determined in Table 2. It shows the Iron ranges from 110 to 310 µg l^{-1} during the winter and in the spring from 240 to 640 µg l^{-1}. Manganese is an essential element and co-factor for several enzymatic reactions. Its concentration ranges from 100 to 220 µg l^{-1}during the winter, while in the spring ranges from 110 to 340 µg l^{-1}. Cadmium ranges from 0.00 to 3 µg l^{-1} during the winter and the spring ranges from 1 to 3 µg l^{-1}. Zinc is a ubiquitous important trace metals and is considered to be relatively nontoxic[2]. Zinc concentration ranges from 12.2 to 54.6 µg l^{-1} during the winter, and the spring ranges from 1.8 to 14.4 µg l^{-1}. Copper concentration ranges from 9.5 to 13.4 µg l^{1} during the winter and 6.33 to 11.5 mg l^{-1} during the spring. Lead is the most ubiquitous toxicant in the environment[27]. Therefore, body levels depend on the environmental conditions of exposure. Lead concentration ranges from 17.3 to 30.2 µgl $^{-1}$ during the winter and from 7.5 to 13.2 µg l^{-1}in the spring.

2.3 Hydro-chemical evolution of the Surface of Ismailia canal

The Piper trilinear diagram[17] is a common method used for the description of hydro-chemical progress and reorganization of the dominant processes that control water chemistry. This diagram was afterward modified by Back and Hanshaw (1965) to separate the water type categories that form the basis for one general classification scheme for natural waters. Moreover, mixing of water from various sources or evolution pathways can also be cleared by this diagram[10]. Fig.2 Shows the hydro-chemical division represented by water types of surface Ismailia Canal is categorized into different water types containing Ca-Na-Mg-HCO_3 or (Na-Ca-Mg-HCO_3), Ca-Mg-Na-HCO_3 Ca-Mg-Na-HCO_3-Cl, Mg-Ca-HCO_3-Cl-SO_4, Mg-Ca-Na-HCO_3-Cl-SO_4. The results show that the predominant type is Ca-Na-Mg-HCO_3. These water types indicate the predominance of bicarbonate alkaline earth waters with higher alkali contents, but with a general tendency towards no dominant cation water type. The pH range is 7.9-8.3 in the winter season and 8-8.4 in the spring season reflecting the slightly alkaline water.

Gibbs[12] showed that a plot of TDS versus the variation in Gibb's ratio of Na/ (Na + Ca) will give important knowledge about three main processes controlling surface water chemistry: (1) precipitation dominance, (2) rock weathering dominance and (3) evaporation crystallization dominance. The weight ratio to TDS was plotted in Fig.3. Depend on Gibbs' ratio, the samples of the winter and summer seasons, located in the rock dominance area. The diagram indicates that the chemical weathering of the rock dominance is the major mechanism. This contributes to the ions of the canal water.

2.4 Water quality evaluation

Data got by geochemical analysis of Ismailia Canal water was evaluated to its convenience for drinking and irrigation uses.

2.4.1 Hydro-chemical impact of environmental deterioration

The hydro-chemical parameters of the canal water of the investigated area were compared with the limit of [26]. This is important to estimate the water suitability for drinking and other purposes. The low concentration of chloride and sulfate of samples studied from Ismailia Canal stops subjacent sources of bad water quality that may be created due to the proximity to the biological influences and contaminated point sources (industrial and sewage). These are for all stations, except the last station had almost high concentrations of Cl^- and SO_2^{4-} (Fig. 4). The chloride and sulfate levels are high, suggests the sodium and potassium are derived from mixing with other polluted sources of water. Concentrations of nitrate are lightly more than the permissible limit of 50 mg l^{-1} in the some analyzed water samples. Also, this is a significant indicator of domestic, agricultural and industrial contaminations[24]. This leads to decreasing of the oxygen carrying capacity of the blood[18]. The values of the total dissolved solids and the electrical conductivity also indicate generally the salinity hazard of the irrigation water. Heavy metals are known to be potentially toxic due to their ability to be accumulated in organs of aquatic organisms and fish. The cadmium is very toxic to humans found in low concentrations. The values of lead exceed the limit (0.01 mg l^{-1}) for drinking water[26]. Overload of Fe causes hepatic cirrhosis and renal failure. In general the study shows that Cd concentrations were found in permissible limits.

2.4.2 Water quality of irrigation use

The type of the irrigation water quality of the canal is determined by salts originated from anthropological and natural sources**.** Electrical conductivity is the most important parameter of salinity hazards and evaluates the suitability of irrigation water**.** Several factors that the status of Ismailia canal depend on, such as electrical conductivity (EC), Total dissolved (TDS), Sodium Percent (%Na), magnesium hazard (MH), sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) are shown in table1. All heavy metals concentrations except the iron found in permissible limits.

Percent sodium (% Na)

The suitability of water for irrigation n mainly depends on sodium percentages. The permeability of soils and plowing are caused by high levels of sodium. This can cause dangerous levels of exchangeable sodium in most soils that will require exacting soil management as good drainage, organic matter additions and high leaching. The Na% value is estimated at the following equation[22]:

$$\boldsymbol{Na\% = \frac{Na^+}{(Na^+ + Ca^+ + Mg^{2+} + K^+)} \times 100} \qquad (1)$$

The concentrations are expressed in meq l^{-1}. The water categorized into four groups according to sodium percent: excellent (>20%), good (20-40%), permissible (40-60%), Doubtful (60-80%) and unsuitable (<80%) [20]. The Na% in the Ismailia Canal ranges from 25.7% to 37.7% in the winter season and from 18.32% to 43.34% the in the spring season. It shows that all of the canal water samples are good for irrigation.

Magnesium hazard (MH)

Magnesium ions are essential for the plant growth. Magnesium hazard (MH) value of irrigation water is calculated by the Szabolcs and Darab[21] following equation:

$$\boldsymbol{Magnesium\,ratio = \frac{Mg^{2+}}{(Mg^{2+} + Ca^{2+})} \times 100} \qquad (2)$$

The magnesium ratio values of the investigated area range from 45.7% to 49.8% in the winter and from 46.6% to 49.6% in the spring (Table 1). When magnesium ratio increases more than 50 are considered to being destructive and not proper for irrigation purpose, and this has badly influence on the harvest yield because the soils turn into more alkaline. The data of water samples show that most all of the canal water samples are not exceeding the magnesium ratio of 50.

Sodium adsorption ratio (SAR)

The main term of the estimation of the suitability of irrigation water is SAR, because it is responsible for the sodium hazard. The soil hardness can be increased from soil dispersion and this cause reduced of percolation rates of the soil surface and decreases the hydraulic conductivity of it. Moreover, unwanted impacts on changing soil properties such as bad aeration, decreasing soil permeability and soil crusting can be attributed to higher SAR values. Dehayer *et al.*,[6] showed that the soil properties may be changed from high levels of sodium in irrigation water and decrease its fertility due to alkalization and Stalinization processes. The relative proportions of sodium (Na^+) to calcium (Ca^{2+}) and magnesium (Mg^{2+}) is determined by the SAR value of irrigation water and The its value was determined depending on the analytical results of sodium ,calcium and magnesium of the sample. The SAR values of the investigated area can be described as follows given by (Hem, 1991) as:

$$\boldsymbol{SAR = \frac{Na^+}{\sqrt{Ca^{2+}+Mg^{2+}}}} \qquad (3)$$

All values of the SAR of irrigation water of the Ismailia Canal are low. According to the USSL (1954) classification **(**Fig. 5), all samples of the investigated area are found in the C2S1 (low salinity and medium low alkalinity). In irrigation water, the total concentration of soluble salts can be described for the reason of categorization of irrigation water as very high (2 250–5 000 μS/cm), high (750–2 250 μS/cm), medium (250–750 μS/cm) and low (EC < =250 μS/cm) salinity region. Exceeding EC values lead to decrease negative sodium impacts, however it can at the same time cause crop stress .The calculated SAR values vary from 0.84 to 0.969 in the winter and 0.879 to 1.123 in the spring and locate in good SAR class. The study showed that all of the samples are of the better class group of irrigation. Therefore, all canal water is good for irrigation and can be used in all soil types.

Residual sodium carbonate (RSC)

Physical properties of soils can be damaged by the high concentration of sodium carbonate and bicarbonate because it causes disintegration of organic matter in the soil. In irrigation water having an excess concentration of $HCO_3^–$, the Mg^{2+} and Ca^{2+} cations favor to precipitate as $CO_3^{2–}$. Residual Sodium Carbonate (RSC) may be indicated the effect of HCO_3^- and CO_3^- ions on water quality[8]. Residual sodium carbonate (RSC) is calculated by following the equation[19]:

$$\boldsymbol{RSC = \left(CO_3^{2-} + HCO_3^-\right) - (Ca^{+2} + Mg^{+2})} \qquad (4)$$

Excess values of residual sodium carbonate (RSC) lead to precipitate of magnesium and calcium and also, disintegrate the soil structure because it traps the air and water movement through soil. The RSC value of the canal water samples ranges -1.29 to 0.79 in the winter and -1.55 to 0.26 in the spring season (Table 1).

Permeability index PI

Permeability index (PI) is an important term of determining the suitability of irrigation and it shows that long term use of irrigation water affects the soil permeability as affected by Ca^{2+}, Mg^{2+}, Na^+ and $HCO_3^–$ contents of the soil. Permeability index can be expressed by the following equation[7]:

$$\boldsymbol{PI = \frac{Na^+ + \sqrt{HCO_3^-}}{(Ca^{2+}+Mg^{2+}+Na^+)} \times 100} \qquad (5)$$

Water can be divided into three categories: (I) with 25 % of maximum permeability is inappropriate for irrigation (II) with 75% of maximum permeability is good for irrigation (III) with 75% more of maximum permeability also are good for irrigation. The PI value of the canal water ranges 56.4% to 73.64 % in the winter and 51.43 to 88.53 in the spring season (Table 1).

Table 1: The statistical summary of hydro-geochemical parameters of six stations of Ismailia Canal

	Winter		**Spring**	
	Average	**Mean**	**Average**	**Mean**
Air Temp ◦C	19-24	22.1	35-39	37.9
Water Temp ◦C	18-23	20.4	33-35	33.5
Transparency	50-75	66.7	70-85	75
EC	341 – 351	347.3	382 - 440	385.9
TS (mg/l)	212.6-266.5	242.8	207.4-220.2	214.1
TDS (mg/l)	175.4-216	190.9	149.8-167.8	155.9
TSS (mg/l)	44-66	22.8	52.4-64.5	58.1
pH	7.9-8.3	8.1	8-8.4	8.2
CO_3^- (mg/l)	3.2-6	4.4	2.4-4.1	3.1
HCO_3^- (mg/l)	190-220.1	206.3	140.8-170	155.1
Cl^- (mg/l)	24.9-95.4	43.3	20.8-79.3	28.1
SO_4^- (mg/l)	32.9- 95.5	84.9	28.2-34.9	25.4
Ca^{+2} (mg/l)	36.9-56.4	47.7	15.7-35.4	26.1
Mg^{+2} (mg/l)	26-40.4	32.8	11-28.5	17.8
Na^{+2} (mg/l)	35.7-50.3	34.5	21.6-38.65	19.9
K^+ (mg/l)	7.7-12.7	9.9	4.3-7.7	6.1
DO (mg/l)	8-9.1	8.6	6.4- 7.7	6.8
BOD (mg/l)	4.6- 6	5.3	2.5-3.9	3.2
NO_2^- (mg/l)	5.9- 7.9	6.4	2.2- 4.3	2.9
NO_3^- (mg/l)	30.6-54.2	35.8	10.1-52.2	20.7
NH_3 (mg/l)	0.43-1.13	0.76	0.4-0.7	0.6
PO_4^{-2} (µg/l)	33.7-65.4	48.8	45.9- 91.9	64.5
TP (µg/l)	115.5- 338.7	245.7	243.1-380.4	312.7
Na%	20.7-38.2	25.8	20.7- 38.2	27.1
RSC	-1.22- 0.729	-0.34	-1.55- 0.26	-0.67
SAR	0.66-1.68	0.89	1.006- 1.61	0.97
PI	78.3-147.5	62.9	52.2- 74.9	67.3
MH	45.7-49.7	48.91	46.6- 49.6	48.5

Table 2: Heavy metals of Ismailia canal

	Autumn		**Summer**	
	Average	**Mean**	**Average**	**Mean**
Fe	110 – 410	310	240 - 640	380
Mn	110 - 220	170	110 – 340	140
Cd	0 - 3	1	1 - 3	2
Zn	12.2 - 54.6	34.1	1.8 - 14.4	7.8
Cu	9.5 - 13.4	12.02	6.33 - 11.5	8.22
Pb	17.3 - 30.2	23.47	7.5 - 13.2	9.4

Fig. 1: Map of the study area

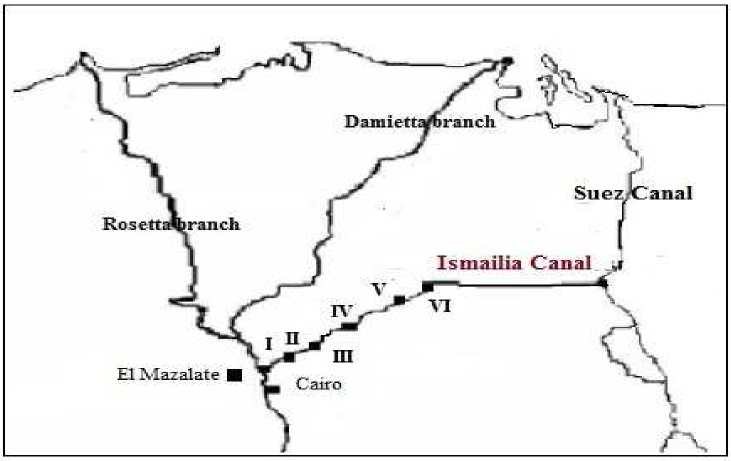


Fig. 2 Piper diagram of major ion chemistry for canal water

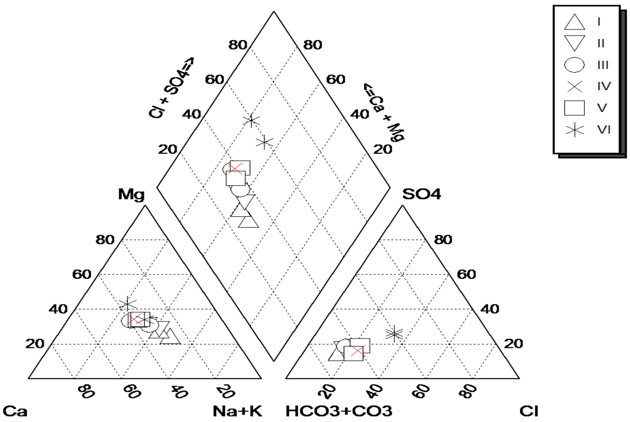


Fig. 3 A Gibbs diagram indicating the most expected process responsible for hydrochemistry of the canal (after Gibbs 1970)

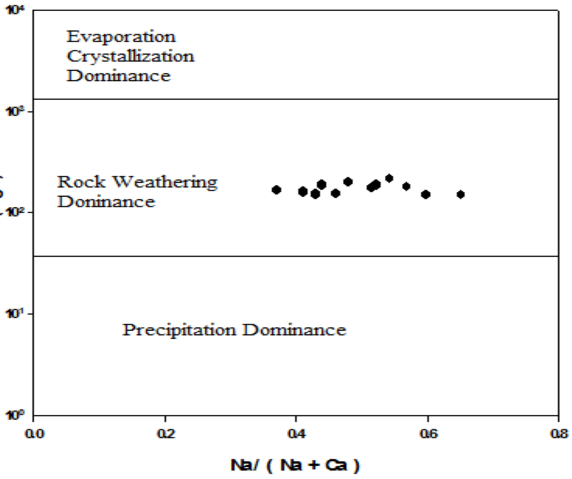


Fig. 4: Ludwig Langleir diagram of the Ismailia Canal

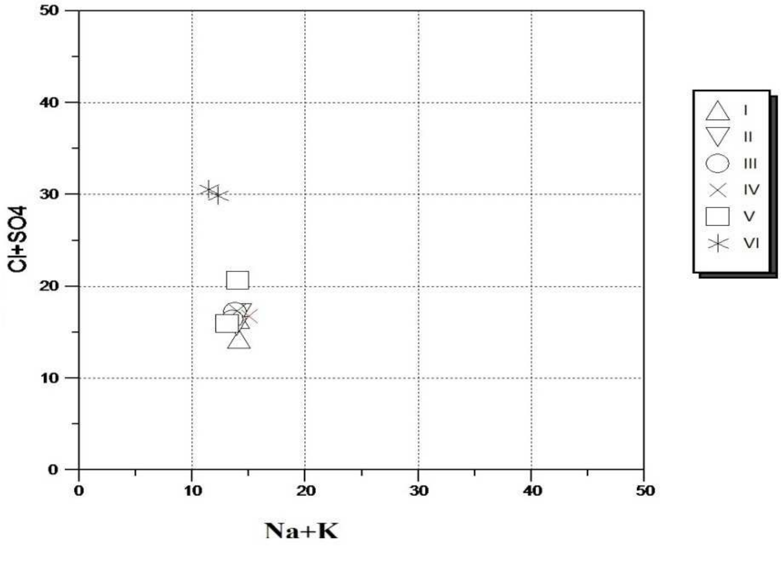
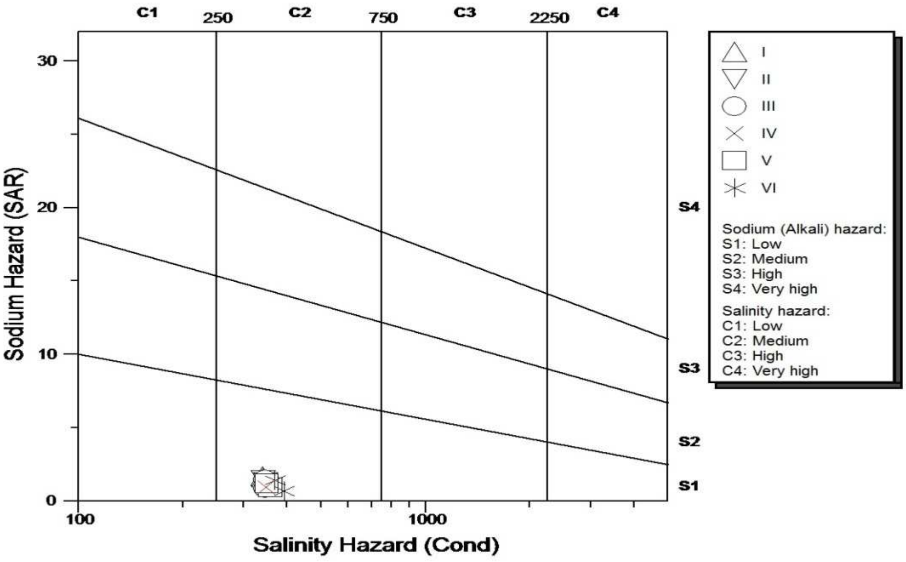


Fig. 5: The relationship between SAR and EC characterizing the irrigation quality of canal water



CONCLUSION

Chemical characterization of canal water of Ismailia was assessed by a relativistic approach to increase an understanding of the most important processes that influenced the hydro-chemical variations. The water quality was also evaluated with respect to its suitability for human uses and irrigation activities. Major conclusions of this study were:

1. Bicarbonate is the dominant anions and there are no dominant cations in the samples. According to the Gibbs diagram, the canal is dominated by rock weathering. The river water type (Na-Ca-Mg-HCO3) in the dominated type water.
2. Physicochemical parameters were used to estimate the quality of canal water for determining its suitability for irrigation purposes and human uses. Calculated values of the RSC, SAR and %Na show that most of canal water is convenient for irrigation. But not recommended for drinking water because of iron concentrations.

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