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Surface water is an important source of water supply for irrigation purpose and in urban areas, sewage water is being disposed of in nearby canals without treatment. A study was conducted to investigate the dynamics of water quality of irrigation canal as a result of this practice. The study ascertained the impact of different salinity parameters, indices and approaches to examine the hazardous effects on quality of canal water. The study analyses the samples collected for various parameters like pH, TDS, EC, Na, Cl, Ca, Mg, K, CO?, HCO? etc. It helped to decide the restriction on use of water based on FAO-UN guidelines. Investigations were focused on assessment of contaminants affecting the quality of water and having hazardous effects on different stages of irrigation water usage. Wilcox diagram and Doneen's approach-based analysis helped to identify the class and quality of water. This study shall help to analyze the quality of water and provide support to the decision makers for better water resource management and policy development for irrigation purpose i.e., treatment and distribution of water resource.

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Article

Dynamics of Water Quality: Impact Assessment Process for Water Resource Management

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Abstract: Surface water is an important source of water supply for irrigation purpose and in urban areas, sewage water is being disposed of in nearby canals without treatment. A study was conducted to investigate the dynamics of water quality of irrigation canal as a result of this practice. The study ascertained the impact of different salinity parameters, indices and approaches to examine the hazardous effects on quality of canal water. The study analyses the samples collected for various parameters like *pH*, TDS, EC, Na, Cl, Ca, Mg, K, CO_3, HCO_3 etc. It helped to decide the restriction on use of water based on FAO-UN guidelines. Investigations were focused on assessment of contaminants affecting the quality of water and having hazardous effects on different stages of irrigation water usage. Wilcox diagram and Doneen's approach-based analysis helped to identify the class and quality of water. This study shall help to analyze the quality of water and provide support to the decision makers for better water resource management and policy development for irrigation purpose i.e., treatment and distribution of water resource.

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1. Introduction

Water resources play a vital role in human life for drinking as well as irrigation purpose. Different approaches were opted to ensure water quality for protecting human health. Multi criteria decision-making techniques were employed by evolving Drinking Water Quality Index (DWQI) and Irrigation Water Quality Index (IWQI) in agricultural field [1]. Sometimes sewage water source is utilized to overcome paucity of water, thus sewage treatment plants are required to be constructed to tackle with hazardous effect of toxic salts and lethal heavy metals. Different criteria are framed to examine water quality. Environment Protection Agency (EPA) is also engaged to ensure quality of drinking as well as irrigation water [1]. Researchers also applied water quality index models with the help of 40 parameters including values of DO, BOD, phosphate, color, turbidity, T. coli, E. coli, Enterococci, iron, manganese, arsenic, aluminum, boron, and barium etc. for quality assessment of drinking water of Kirmir Basin (Turkey) [2]. Water quality index was evolved in the analysis of Al-Gharraf River (Iraq) based on 11 parameters. Water quality indices, which influence on different environmental impact, were evolved to help humans by improving quality of water [3]. Similar approach was also implied on Sapanca Lake Basin (Turkey) in collaboration with Canadian Council of Ministers of the Environment Water Quality Index (CCME-WQI), Oregon Water Quality Index (OWQI) and National Sanitation Foundation Water Quality Index (NSF-WQI). This approach finally inferred the risk of eutrophication for Sapanca Lake [4]. Based on Canadian DWQI, a new drinking water quality index was developed, designated as "modified DWQI. In development of the modified DWQI, 23 quality parameters were involved to standardize the quality of safe drinking water. The study showed that the modified DWQI and its sub-indices are very beneficial for defining the overall water quality easily [5]. Sometimes decision-making approaches are needed to assess the quality of water. Different water quality approaches such as Fuzzy logic [6], Regression Analysis [4], Weighted Athematic [3], Ordered weighted Averaging and TOPSIS [1], Multivariate Analysis [7], Spearmen's rank correlation [8] and neural networks [9] are exercised in making the decision on quality of water. But monograph-based techniques like Wilcox's [10] and Richards's [11] and Doneen's [12] approach are easy to adopt and implement for management and policy development purpose.

The aim of the study is to assess the quality of water in relation to the concentration of soluble salts which have hazardous effects on different stages of crop growth. The study is helpful in finding the level of restriction in using irrigation water defined by FAO-UN guidelines. Determination of concentration of salinity parameters also helps water resource managers to decide in applying requisite management techniques such as amount of leaching required, devising methods in improving the rate of infiltration, application of various adequate chemicals helpful in reducing the concentration of salts or extra ordinary techniques in presence of excessive salt concentration. In order to investigate the water quality level of the irrigation water, besides finding rate of infiltration based on Doneen's approach, this study also aims at finding salinity water class based on well renowned Wilcox and Richard's approach.

2. Materials and Methods

2.1. Study Area

The area of study was Faiz distributary that covers a distance of 51.5 km across the district of Lodhran in Pakistan (Figure 1). It was commissioned with authorized discharge of 308 cusecs. Out of Gross Command Area (GCA) of 47294 acres the distributary irrigates the Culturable Command Area (CCA) of 46812 acres. The distributary has been polluted after the inculcation of untreated sewage of 80–100 cusecs from urban areas of Multan district. The inclusion of sewage in the distributary has affected the quality of irrigation water owing to the increased level of salinity and concentration of toxic elements. The only source of application of water to the crops of this region is from this distributary as the tube well source is expensive and underground water is brackish, especially, in the last tract, 17 km in length, till the tail is reached.

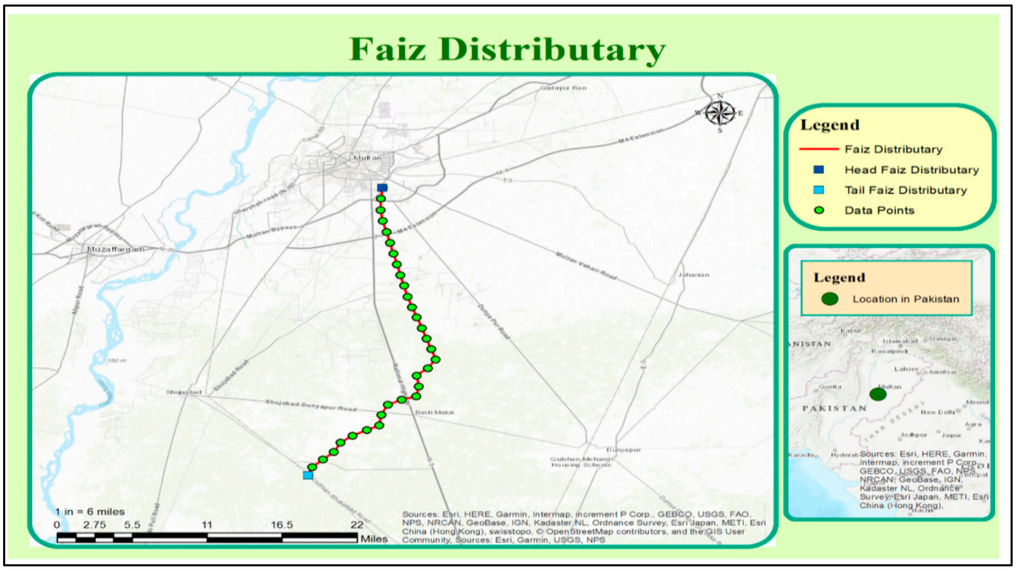

Figure 1. Study area of Faiz Distributary Water Course (Multan-Pakistan).

The distributary is lined to increase the duty and efficiency of the system. This study was carried out to arrive at the determination of quality of water in accordance with level of salinity. The water of this distributary, divided in 32 segments, was sampled after each mile. The study was focused to know the suitability of water based on salinity parameters and different water quality approaches. The segmental view of Faiz distributary shows its track to end at the tail.

2.2. Study Framework

A two-stage framework as shown in Figure 2 has been proposed for water quality analysis and impact assessment. First Phase comprises of Physio-chemical analysis of water samples while second phase is related to identification of safe application of water for irrigation purpose.

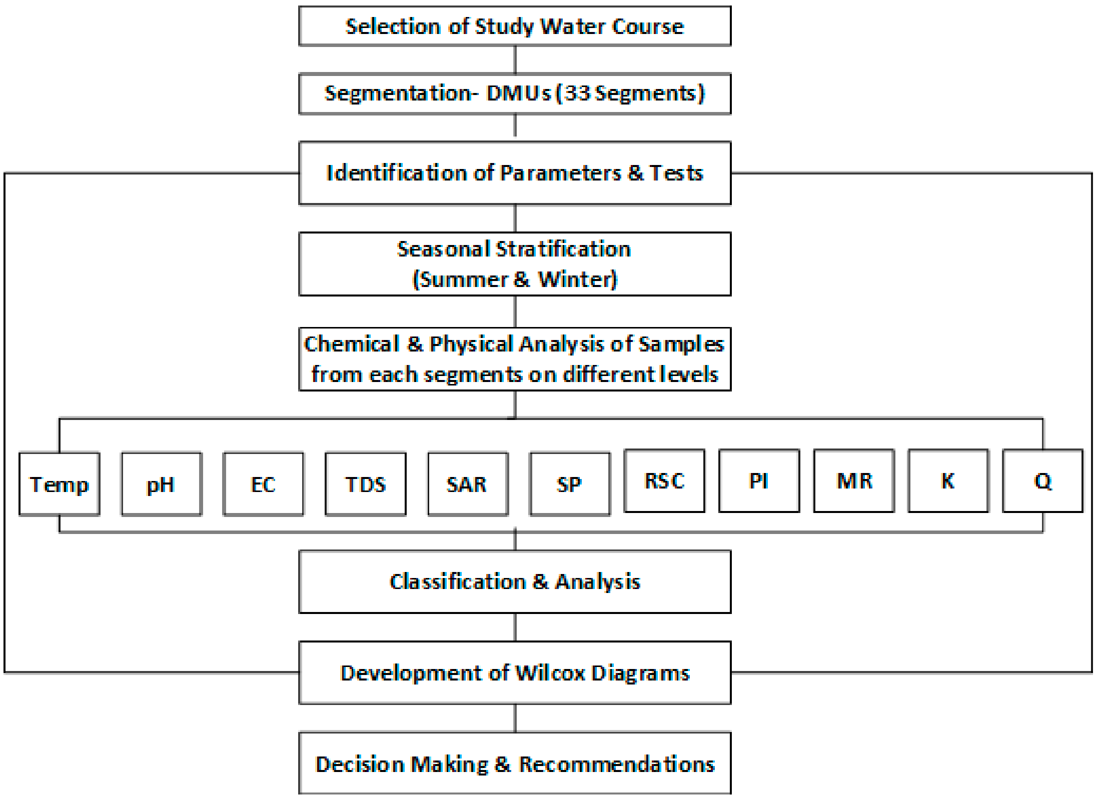

Figure 2. Methodological Framework for Analysis.

Step-wise methodology with an objective of finding water quality class, based on well-renowned Wilcox, Richard's and Doneen's approach and water resource decision management, has been elaborated as follows:

Step.1: Selection of distributary/water course as study area.
Step.2: Adaptation of water sampling technique.
Step.3: Segmentation of distributary/water course with equal intervals.
Step.4: Collection of water sample of each segment of water course in two seasons (Winter/Summer).
Step.5: Selection of critical parameters for water quality analysis.
Step.6: Physical and Chemical analysis of each sample.
Step.7: Comparison of salinity parameters with FAO-UN guidelines for knowing the level of restriction in using irrigation water.
Step.8: Wilcox diagram and Richard's approach in predicting and evaluating water class.
Step.9: Doneen's approach in identifying infiltration problem.
Step.10: Water Resource Management and Policy Implications according to identified problems.

2.3. Sampling and Selection of the Parameters

The collected samples were analyzed to find the extent of salinity based on electrical conductivity. The concentration of cations and anions, various salinity parameters, ratios and indices in relation to these ions, were determined. The presence of excess of sodium was assessed in terms of sodium percent, residual sodium carbonate and sodium absorption ratio. The balance of magnesium relative to the presence of calcium ions in irrigation water was determined based on magnesium ratio. Permeability index, which pertains to the percolation of irrigation water, was another parameter responsible for free flow of water into the pores of soil. These salinity parameters, which affected quality of irrigation water, set an index whether it is suitable or not. The following parameters to be analyzed is tabulated in Table 1.

Table 1. Data Description of Water Parameters with Respect to Depth of Faiz Distributary.

Variable	Description	Mean	SD	Min.	Max.	Med.	Q1	Q3
Q	Discharge (Cusec)	188.1	108.6	5	374	194.5	97.8	280.3
pH	pH Value (1–14)	7.65	0.1739	7.4	8	7.6	7.5	7.8
EC	Electrical Conductivity (dS/m)	0.7849	0.0934	0.632	0.916	0.7975	0.6967	0.877
TDS	Total Dissolved Solids. (mg/L)	506.92	64.94	405	728	526.5	448.5	562.25
Na	Sodium. (meq/L)	4.841	1.143	2.95	6.88	4.825	3.822	5.645
Ca	Calcium (meq/L)	1.6139	0.4236	0.83	2.4	1.66	1.27	1.93
Mg	Magnesium. (meq/L)	1.3203	0.3174	0.75	1.94	1.32	1.0975	1.5375
Cl	Chloride. (meq/L)	3.045	0.7437	1.57	4.29	3.165	2.42	3.6475
HCO3	Bicarbonate. (meq/L)	1.0274	0.3847	0.3	1.72	1.055	0.7	1.37
SAR	Sodium Absorption Ratio.	3.9688	0.5011	3.33	4.72	3.97	3.44	4.3975
SP %	Sodium Percentage.	64.45	2.309	60.7	68.57	64.71	62.12	66.535
PI %	Permeability Index.	75.409	3.38	71.37	82.76	73.99	73.067	77.515
Mg Ratio %	Magnesium Ratio	45.054	1.221	42.23	47.73	44.755	44.248	45.81
K	Potassium. (meq/L)	16.936	3.123	13.23	20.81	16.8	13.88	19.935
Distance	Segments (Miles)			0	32			
Season	S-Summer, W-Winter			S	W			

2.4. Wilcox, Richards and Doneen's Diagram Development

Wilcox, L.V in 1948 [10] classified irrigation water in relation to the concentration of sodium percent as Excellent (SP < 20), Good (SP 20–40), Permissible (SP 40–60), Doubtful (SP 60–80) and unsuitable (SP > 80). By integrating effect of sodium percent and electrical conductivity with defined ranges of 0–250, 250–750, 750–2000, 2000–3000 and >3000 micromhos/cm, Wilcox presented a diagram (Known to be Wilcox Diagram) showing different zones designated by different water classes as Class I (Excellent to Good), Class II (Good to permissible), Class III (Permissible to doubtful), Class IV (Doubtful to unsuitable) and Class V (Unsuitable). This diagram shows decreasing water quality trend with increase in concentration of sodium percent and electrical conductivity [10,11]. In extension to categorizing the water on the basis of electrical conductivity and SAR, Richards [11] made some changes and developed another modified diagram with 16 water classes known as Richards Diagram. Further classification was done on same lines by Doneen [12] in 3 Classes (I, II and III) by considering PI index. This Graphical representation is popular among environmental and water resource researchers and is helpful in assessing the usefulness of water of Mayur River [13], Gediz River [14] Nile River [15] Ile-Ife, Nigeria [16] groundwater of South India [17] groundwater of Ghana [18]. Because of its well-defined pattern and graphical representation, this method has been adopted in this research.

3. Results

The results of the study mentioned in subheadings were elaborately discussed so that the experimental outcome could be concluded based on its suitability for irrigation.

This study involved samples collecting activity applied on whole length of the distributary along its flow to analyze salinity parameters. The samples were collected systematically from top to bottom at each selected interval of mile. This exercise commenced from head regulator to the end of the distributary. Electrical conductivity, cations, anions, *pH* value, TDS and various indices were determined and compared with Food and Agriculture Organization (FAO) guidelines [19] mentioned in Table 2 to ascertain sewage effect on water quality of this distributary.

Table 2. FAO-UN Guidelines for Irrigation Water Quality Parameters [19].

Potential Irrigation Problem	Parameters		Degree of Restriction on Use		
			None	Slight to Moderate	Severe
Salinity	Electrical Conductivity dS/m		<0.7	0.7–3.0	>3.0
	Total Dissolved Solids		<450	450–2000	>2000
Infiltration based on SAR and EC	SAR	Electrical Conductivity (dS/m)			
	0–3		>0.7	0.7–0.2	<0.2
	3–6		>1.2	1.2–0.3	<0.3
	6–12		>1.9	1.9–0.5	<0.5
Toxicity	Sodium (Na) meq/L		<3	3–9	>9
	Chloride (Cl) meq/L		<4	4–10	>10
Miscellaneous Effects	Bicarbonate (HCO_3) meq/L		<1.5	1.5–8.5	>8.5
	Potassium (K) mg/L		0–2		
	pH		6.5–8.4		

3.1. *pH Value*

After analysis of the samples, *pH* value appeared to be more than 7 showing water by nature as alkaline.

The pH values ranging from 7.8 to 7.4 and 8 to 7.4 in summer and winter seasons were found within acceptable range when compared with FAO-UN guidelines [19].

3.2. *Concentration of Ions*

The concentration of all cations and anions showed their declining trend towards last segment of the distributary. The variational range in both the seasons i.e., from 5 meq/L to 2.95 meq/L and 6.88 meq/L to 5.54 meq/L imparts its restriction on using this water as "Slight to moderate" after observing FAO-UN guidelines [19]. High concentration of sodium produces sodium hazard which restrains plants to grow normally. The next high concentration found in water was of chloride ions which is responsible for toxic effect when found in water above desired level. The ranges between 3.40 to 1.57 meq/L and 4.29 to 2.86 meq/L indicate that there is no restriction in using this water in summer while it is "slight to moderate" to "None" in winter when proceeding towards tail of the distributary.

After analysis all the samples were without carbonate whereas the level of calcium and magnesium in both the seasons remained below than 2.5 meq/L and 2 meq/L respectively. No FAO-UN guidelines [19] are available for their restriction on use of water. However, high level of calcium and magnesium in water causes a reduction in SAR and RSC values. Further, bicarbonate level also appeared to be in the range of 0.3 meq/L to 1.72 meq/L which shows its restriction in using this water from "None" to "slight to moderate".

3.3. *Salinity Hazard*

The condition of salinity hazard appeared when salts accumulate around roots zone after continuous supply of saline water. This results into the reduction of up-take of water to the entire plant even in the presence of bulk amount of water that extremely reduced in growth of the plant. Salinity hazard is measured in terms of electrical conductivity and total dissolved solids. Electrical conductivity measures total salt concentration ant its high value indicates salinity hazard and toxicity [20].

After analysis, the values of Electrical conductivity were found decreasing from start to end of the distributary in the range between 0.774 dS/m to 0.632 dS/m and 0.916 dS/m to 0.821 dS/m in both the seasons. The concentration of salts in winter is higher than that in winter as less water is available relative to the amount of salts present in it. After observing ranges of FAO-UN guidelines [19] and ranges of Electrical conductivity it was concluded that the restriction on using this water in summer is “slight to moderate” nearly along the half course of canal and becomes “None” for the remaining course of the distributary till the tail is reached. In winter, observed water use restriction is “slight to moderate” throughout the course of distributary.

Total dissolved solids (TDS) also pertain to the measurement of total salinity. TDS value is obtained from the value of Electrical conductivity [21] and this association of TDS value with electrical conductivity varies proportionately. After analysis, TDS values, ranging from 525 mg/L to 586, obtained in winter appeared to be more than the values obtained in summer that ranged from 425 mg/L to 496 mg/L.

On the basis of the results of TDS and Electrical conductivity, the class of water was also decided in reference to Table 3 based on FAO assessment method [19]. By comparing values of TDS and EC in Table 3, the water in summer is slightly saline” in the first half length of the distributary and becomes “Non-saline” till end of the distributary, while the water is “slightly saline” during whole winter.

Table 3. Salinity water class on the basis of EC and TDS [19].

Water Class	Electrical Conductivity dS/m	Salt Concentration mg/L
Non-Saline	<0.7	<500
Slightly Saline	0.7–2	500–1500
Moderately Saline	2–10	1500–7000
Highly Saline	10–25	7000–15,000
Very highly Saline	25–45	15,000–35,000
Brine	>45	>45,000

3.4. Sodium Hazard

Continuous irrigation causes accumulation of salts resulting in the displacement of calcium and magnesium ions. This phenomenon spoils soil structures and is responsible for the dispersion of soil grains. Displacement of calcium and magnesium encourages consolidation of soil, thus reduces infiltration to make soil impervious [22]. The plant is unable to draw required amount of water which causes reduction in yield. This condition is called sodium hazard. This prevailing condition reduces water quality [23]. Sensitive plants are liable to be affected by this condition. Leaf burn and defoliation is the prominent outcome of sodium hazard.

The term sodium absorption ratio (SAR) is used to express the intensity of sodium hazard [17]. Sodium absorption ratio indicates the amount of sodium relative to the concentration of calcium and magnesium. Excess of magnesium and calcium in water reduces SAR value and flocculates soil grains contrary to the behavior of dispersion of soil particles by sodium of high concentration.

From the results, it was found that the values of SAR in winter (4.72–4.21) were higher than those in summer (3.73–3.33). According to FAO-UN guidelines the restriction on applying water is slight to moderate through the year.

Irrigation water was also classified with the help of Richard’s diagram [24] by United States Salinity Laboratory (USSL) after categorizing water in 16 groups on the basis of SAR and electrical conductivity. The plot of results on Richard’s diagram (Figures 2 and 3) shows water class C_2-S_1.

United States Salinity Laboratory (USSL) also classified irrigation water. According to USSL, the quality of water is categorized in 16 groups on Richard’s diagram based on salinity hazard (EC) and sodium hazard (SAR). The plot of values of EC and SAR on Figures 3 and 4 (Richard’s diagram) shows class as C_2-S_1 expressed as “water of medium salinity with low sodium”.

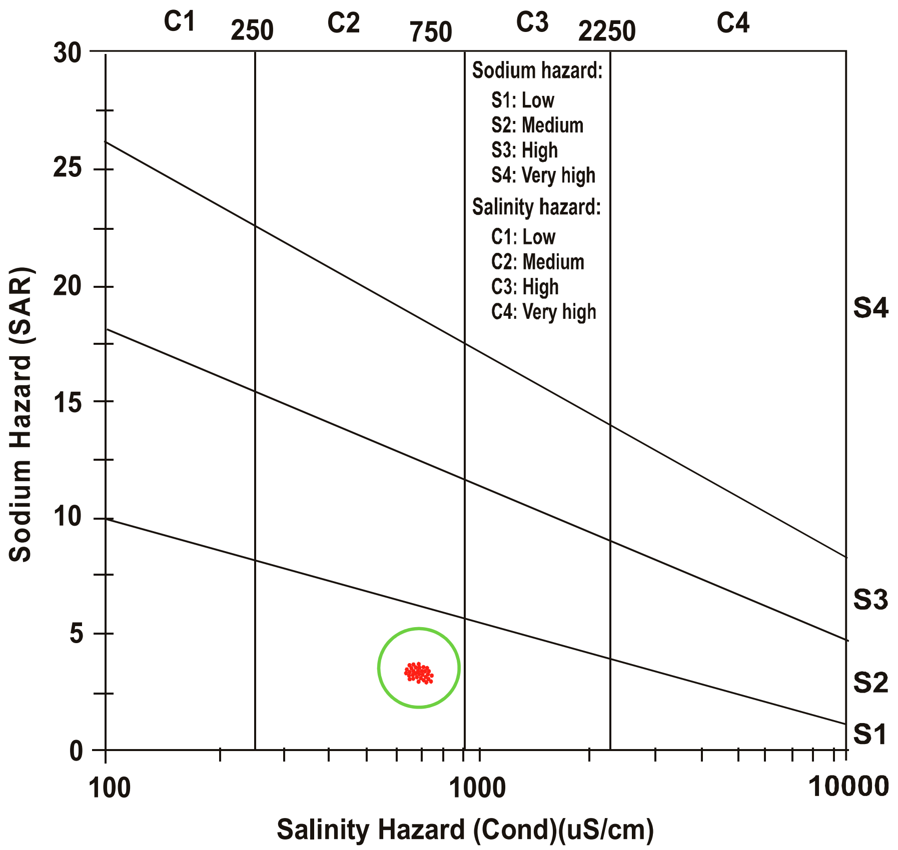

Figure 3. Salinity and Sodium Hazard Class for Faiz Distributary in Summer Season.

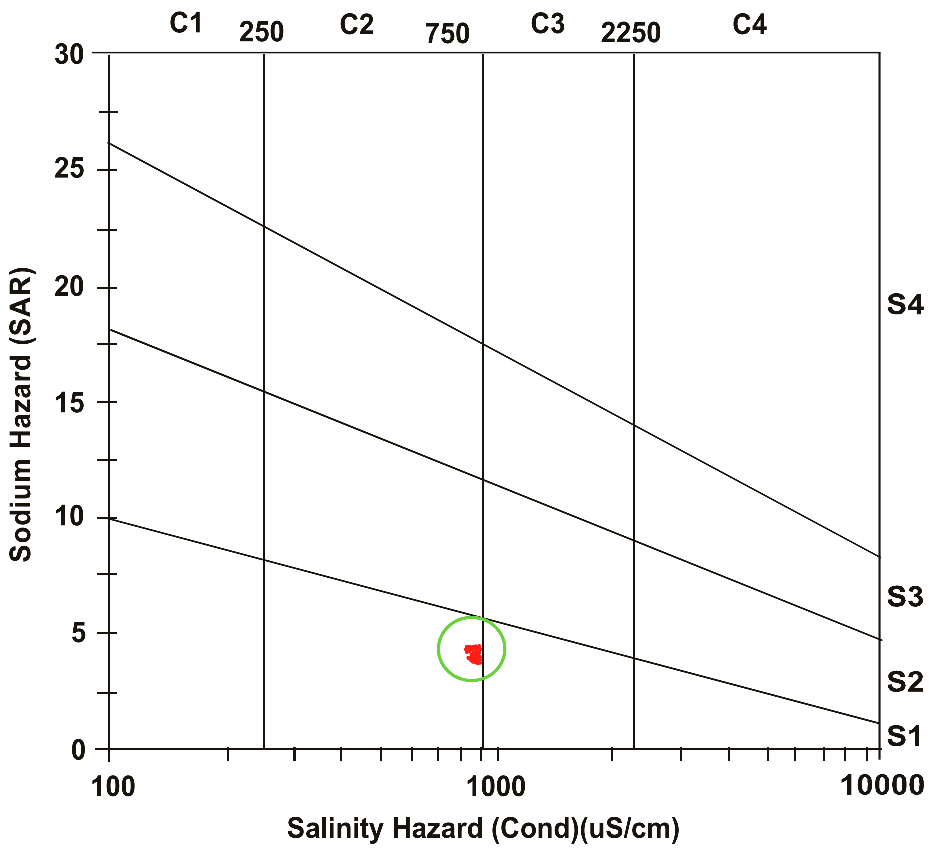

Figure 4. Salinity and Sodium Hazard Class for Faiz Distributary in Winter Season.

3.5. Sodium Percent

Sodium percent is another parameter which relates to sodium hazard. Higher values of sodium percent produce sodium hazard. It was found from the results that sodium percent showed increasing trend while proceeding towards tail of the distributary. There are no guidelines values mentioned by FAO-UN for which restriction on using water may be decided, however, higher value of sodium percent is undesirable as it reduces water quality. Its value from 60% to 70% is, in both seasons, appreciably high to categorize water as "permissible to doubt".

Wilcox diagram (Figures 5 and 6) was also used to classify water depending upon sodium percent and electrical conductivity [25]. From the results and after plotting values, the water class in winter is "permissible to doubt" and transitionally changed from excellent to doubtful in summer season.

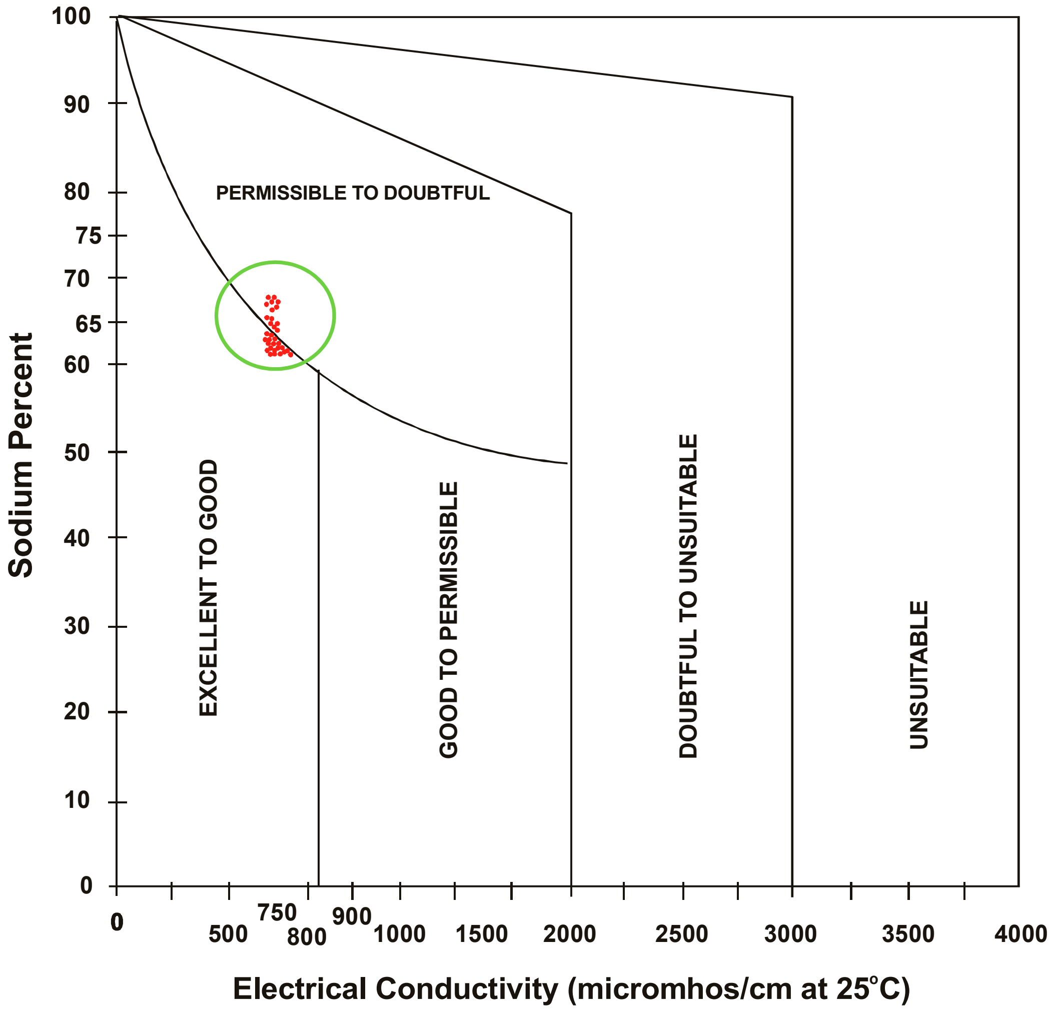

Figure 5. Wilcox Diagram for EC and Sodium Percentage for Summer Season.

3.6. Alkalinity Hazard

High Carbonate (CO_3 and HCO_3) level imparts alkalinity and its excess value produces alkalinity hazard. The presence of carbonates in water could reduce the acidic effect. Carbonates have the tendency to reduce the acidity of water. High alkalinity produces wrecking effect on plant life and causes sodium to absorb easily and reduces rate of percolation of water into the soil. Measurement of alkalinity is taken in term of residual sodium carbonate (RSC) value. High value of RSC shows higher level of carbonates. High alkalinity is not desired as it reduces water quality. RSC shows sodium contents relative to the presence of concentration of calcium and magnesium. Its value should be less than 1.25 meq/L because high value indicates infertility of soil due to deposition of sodium carbonate [25]. From the analysis, it was observed that RSC values remained negative in both the seasons which are less than 1.25 meq/L and the water designated is without alkalinity hazard.

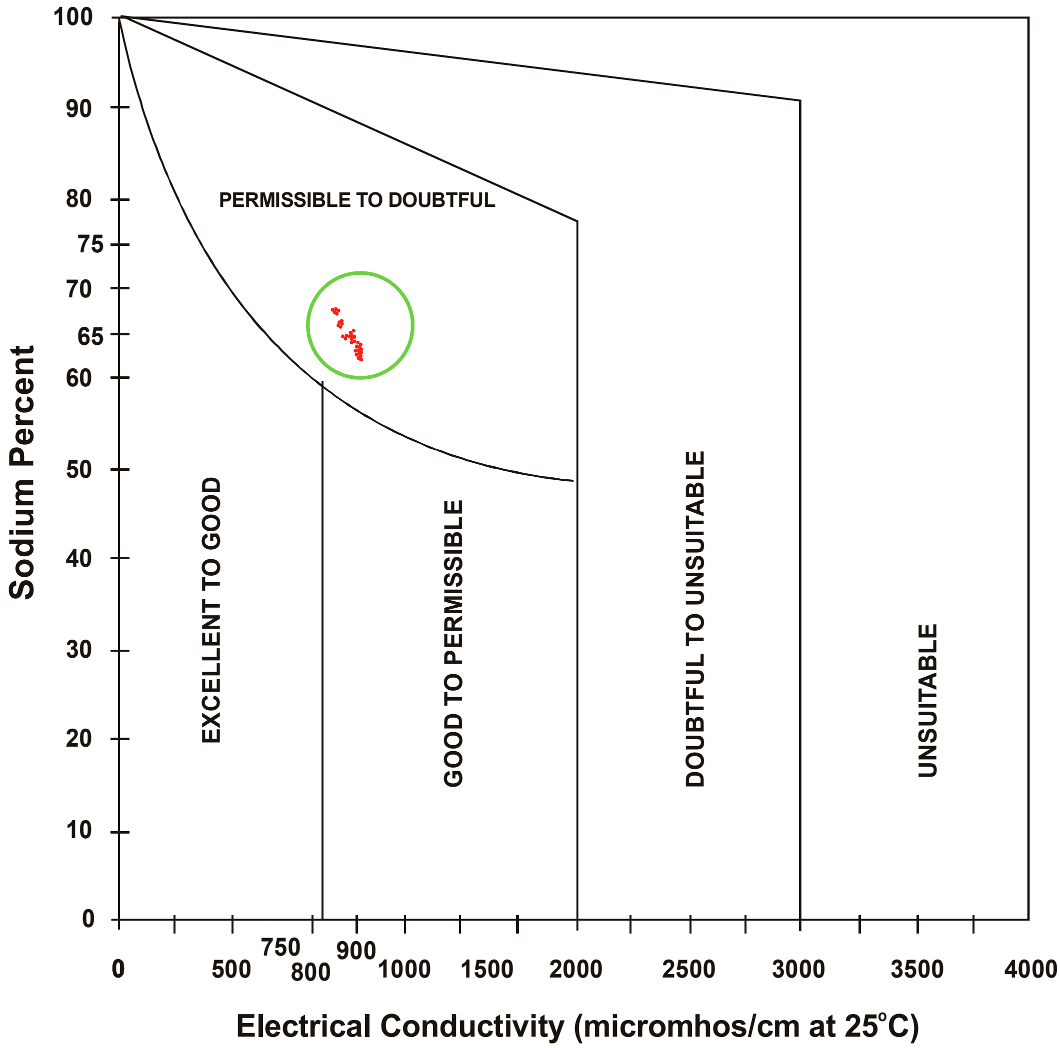

Figure 6. Wilcox Diagram for EC and Sodium Percentage for Winter Season.

3.7. Infiltration of Water

As mentioned earlier, accumulation of salts decreases infiltration of water needed for plants. The plants are unable to get required amount of water; thus, their growth is slowed down. The process of infiltration is affected by higher sodium absorption ratio (SAR) and electrical conductivity (EC) as suggested by FAO-UN [19]. By observing ranges of EC (0.916–0.632 dS/m) and SAR (4.72–3.73) for both summer and winter seasons the degree of restriction is “Slight to moderate” when compared by FAO-UN guidelines in the given Table 2. The effect of infiltration regarding its restriction can be seen vividly by plotting values of EC and SAR obtained from the results after sampling. The plot (Figures 7 and 8) of all values clearly indicates the degree of restriction as “Slight to moderate.”

Doneen, in his work, based on infiltration concept, divided irrigation water into three water classes named as Class I, II and III [12]. The degree of infiltration is dependent on permeability index for which class I and II shows 75% or above 75% percolation and the water is acceptable for irrigation purposes. Class III is not acceptable as it shows PI value less than 25 % [26] (Figure 9). After analysis, Permeability index in summer and winter varied from 72.37% to 82.76% and 71.37% to.74.65% (Table 1) along the course of distributary.

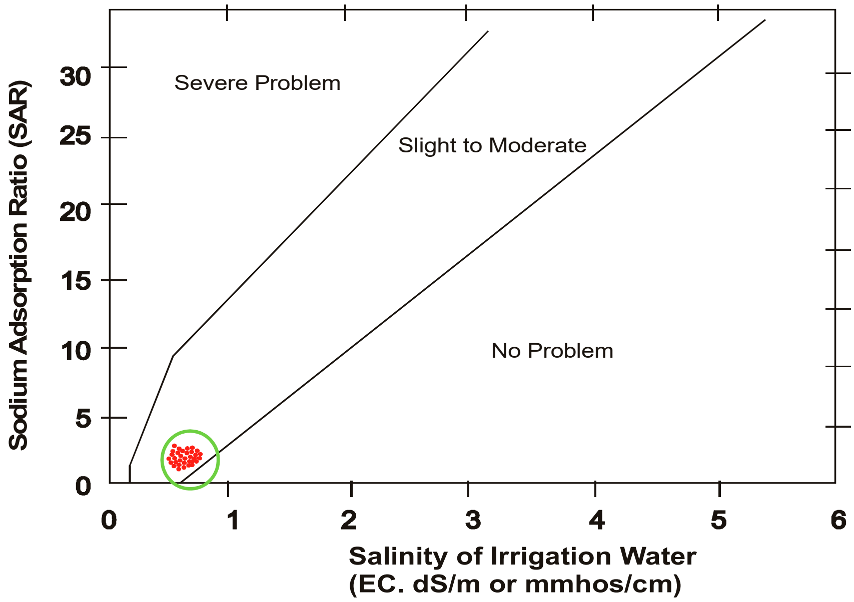

Figure 7. Infiltration problem for summer season.

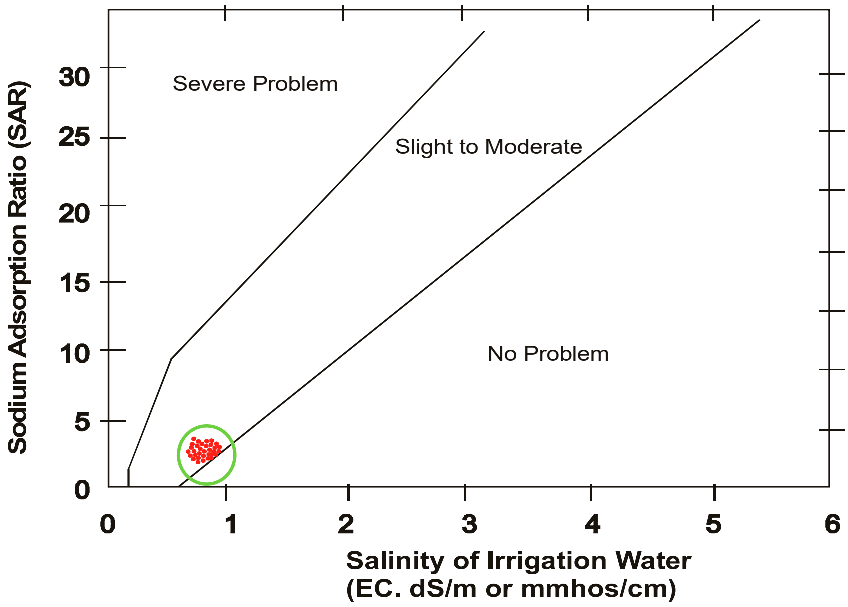

Figure 8. Infiltration problem for winter season.

By observing PI values and apprehending concentration of salts present in water, the water of Faiz distributary changed transitionally towards tail from Class I to Class II in summer season. In winter season the water remained in class I through the length of distributary (Table 4).

Table 4. Permeability Index and Salinity in Terms of Cations and Anions.

Permeability Index (PI)		**Salinity in Terms of Cations and Anions (meq/L)**							**Irrigation Water Class**
Summer season		Na	Ca	Mg	Cl	HCO_3	K	Total	
Minimum	72.37%	4.94	1.96	1.61	3.33	1.49	0.37	13.7	Class I
Maximum	82.76%	3.19	0.92	0.83	1.88	0.8	0.16	7.78	Class II
Winter season									
Minimum	71.37%	5.62	1.88	1.47	3.64	0.84	0.51	13.96	Class I
Maximum	74.65%	4.86	1.4	1.13	3.08	0.42	0.5	11.39	Class I

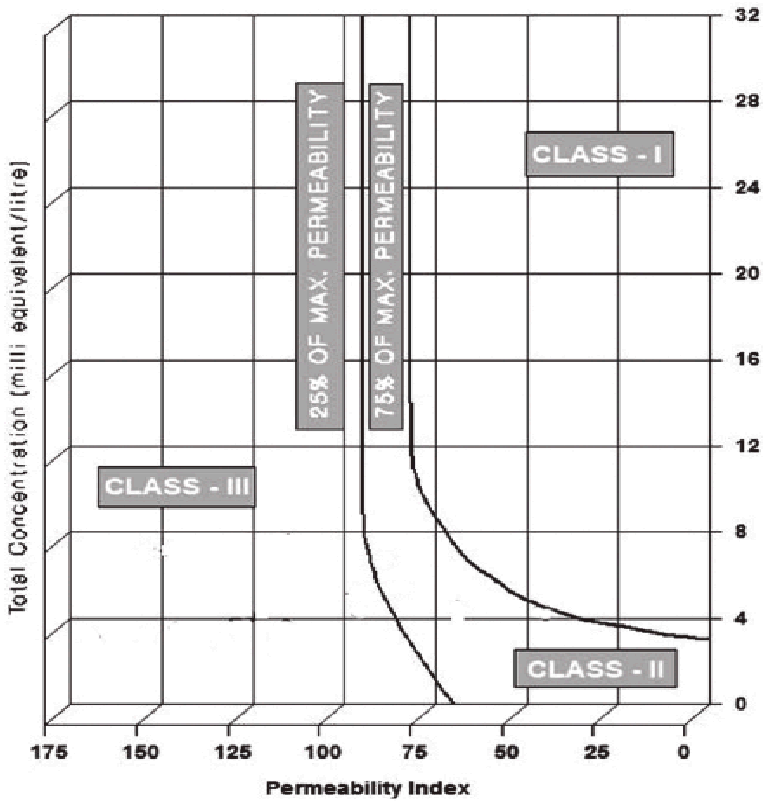

Figure 9. Doneen's Classification of Irrigation Water.

3.8. Magnesium Ratio (Magnesium Hazard)

The concentration of calcium and magnesium generally exists proportionately and maintains a certain ratio, called Magnesium ratio, in water. Magnesium ratio is an important parameter which shows magnesium concentration in relation to calcium present in water. When concentration of magnesium exceeds, it causes magnesium hazard, thus affects different growth activities of the plants. No guidelines by FAO-UN have been suggested in this regard. However, the threshold level of magnesium ratio (MR) is 50%. The water is fit for irrigation if MR is less than 50% [27]. When magnesium ratio is more than 50% it involves many adverse implications towards its growth and lesser yield [27].

After analysis of the samples taken in summer from Faiz Distributary, values of magnesium ratio came to be in the range of 44.03%–46.69%, while in winter, it was in between 42.23%–45.90%. For both seasons, the water is acceptable for irrigation purpose as MR is less than 50%.

3.9. Policy Implications

From the results of the study, it can be apprehended that continuous application of irrigation water containing considerable amount of untreated sewage water may become unhealthy as the water contains toxic matters harmful for human beings, animals and whole ecosystem. It is better to evolve proper disposal and treatment system of urban and industrial sewage by the policy makers instead of dropping it directly into the distributary. Drop of sewage water in unlined distributary may increase salinity level of the ground water. To avoid the increased salinity level, water quality standards should clearly be applied and observed. It is further inferred from the results that mixing of sewage water in the designed discharge causes de-shaping of longitudinal section of the distributary that cause extra expenditures for maintaining the section in its true dimensions. Two main policy implications can be noted regarding water quality analysis and decision making, as either water is used after recommended treatment under existing conditions or even type of crop can be changed which will totally revolutionize the agricultural production process due to change of crop production. This is because some crops are not affected by certain water pollution or level. The water which is not suitable for a crop can be suitable for another certain crop.

4. Conclusions

In this study, water quality of the Faiz Distributary (water course) and its suitability as irrigation water were evaluated with the help of Wilcox's, Richards's and Doneen's Method. The Faiz Distributary (water course) is the main water resource attached with Multan region for irrigation purpose. To evaluate water quality of the water course, 32 sampling sites were determined, and a series of water quality parameters were selected for seasonal monitoring and analysis. After analysis and discussion, series of derived conclusions are:

(1) The concerned aspect of this study was to address total salinity of irrigation water. After analysis and comparing with FAO-UN guideline [19], the study revealed that the water is "slightly saline" concluded on the basis of electrical conductivity. It was further apprehended that salinity level, depending on EC values, decreased along the flow till the tail reached. According to the FAO-UN guidelines, being nature of water as slightly saline, the restriction on using this water is "slight to moderate".

(2) The water was also tested to judge its extent of basicity which showed its nature as alkaline. The other parameters pertaining to salinity were also analyzed to ascertain concentration of water and its classification based on different approaches. Sodium absorption ratio is also an important parameter which indicates the extent of sodium hazard when sodium is in excess. SAR is reduced when magnesium present in water is enough. In the analysis it was found that SAR reduced along the course of flow towards tail in both the seasons and the restriction of using this water is "Slight to moderate" and the water is designated as "Low sodium water" based on FAO-UN guidelines.

(3) After defining a correlation between EC and SAR, United States Salinity Laboratory (USSL) determined water class as "medium salinity with low sodium" (C2 S1) for both the seasons.

(4) Sodium percent (SP) not only predicts the concentration of sodium but also causes sodium hazard when found in excess. Plot of sodium percent (SP) and electrical conductivity established water quality as "permissible to doubt full in summer and gradually converted from "excellent to good" to "permissible to doubtful". The condition of water indicates that the sodium percent is slightly higher, thus, affecting water quality.

(5) Alkalinity level was found well below threshold level; therefore, no alkalinity hazard exists. The water for irrigation is Good.

(6) Up take capacity of water by plant is considerably affected in the presence of accumulated salts which reduce rate of infiltration. The analysis found that this problem has occurred and is "slight to moderate." Rate of infiltration is also governed by permeability index (PI) which indicates the degree of infiltration suggested by Doneen. It was concluded that water in summer transitionally changed from class I to Class II along the course of flow and is good for irrigation purpose, while in winter it pertains to class I.

(7) The water was also analyzed based on magnesium ratio (MR) that indicates magnesium hazard if it is greater than 50%. The results indicate that no magnesium hazard exists in both the seasons and the water can be used for irrigation purpose.

(8) Chloride toxicity was also apprehended based on FAO-UN guidelines and it was found that restriction on using this water is "slight to moderate."

The above said conclusions, also presented in tabular form (Table 5) below, clearly show quality of water in context of class of water and rate of restriction in using this water.

Table 5. Conclusive Analysis-Water Quality of Faiz Distributary (Water Course).

Potential Irrigation Problem	Parameters	Degree of Restriction on Use [FAO-UN]	Quality of Water
Salinity	EC	Slight to Moderate	Slightly Saline
Sodium Hazard	SAR	Slight to Moderate	Low Sodium Water
	SP and EC (Wilcox diagram)	-	In summer "permissible to doubt" and in winter transitional state from "excellent to good" to "permissible to doubtful"
	SAR and EC (Richard's Diagram)	-	Medium Salinity with Low Sodium
Toxicity	Na Cl	Slight to Moderate Slight to Moderate	- -
Alkalinity Hazard	RSC	None	Good
Infiltration Problem	SAR and EC	Slight to Moderate	-
	PI and Total Salinity	-	Class I and II in Summer and Class I in Winter (Good)
Magnesium Ratio	MR	-	Suitable for Irrigation.
Decision: Water cannot be used for irrigation purpose-based FAO guideline without recommended treatments.			

After summarizing quality of water in tabular form, it is clearly ascertained that problem of salinity has occurred due to mixing of sewage into water designating it as "Slightly to medium saline with low sodium". The restriction on use of water of Faiz distributary is "Slight to moderate". It is pointed out further with grave concern that sensitive crops and orchards have been affected by using this water. The low sodium water is considered as unsuitable for sensitive crops which may cause a great damage on roots, stems, leaves and ultimately yield. According to the agronomists, yield is lowered if electrical conductivity exceeds 0.7 dS/m. Suitable techniques such as leaching, addition of chemicals in lowering concentration of salts, are required to be applied by the agriculturists engaged in water resource management. In future continuous use of irrigation water of Faiz distributary, mixed with untreated waste water, may reduce rate of infiltration considerably causing further accumulation of salts near root zone of the crops grown in the study area.

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