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Irrigation Water Quality Based on Hydro Chemical Analysis, District Rahim Yar Khan, Pakistan

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Abstract
The global renewable fresh water resources are finite and are rapidly diminishing due to increase population at an alarming rate. This situation inclined the former community to switch over to alternative strategies. Water use practices in the country are not in accordance with water conservation and quality requirements. Tube well water is one of the most common resources to support the irrigation in situation of canal water scarcity. However, tube well water has its bad effects on soil properties and crop yield, considering the importance of tube well water, present study was conducted for the quality assessment of tube well water to provide guidelines to farmer and researches for better crop production by adopting water management strategies. Tube well water quality is major contribution factor towards the low yields of crops in Pakistan, as it is not fit for irrigation in most of the areas. Total 17337 water samples were collected from all the four tehsils of district Rahim Yar Khan during the year July 2003 to June 2010. These samples were analyzed and categorized according to suitability criteria of water quality evaluation. 45 percent water samples were found fit, 11 percent were marginally fit and 44 percent water samples were found unfit for irrigation purpose. Majority of water samples were found hazardous for irrigation purpose. There is need to analyze the existing water resources and recommending comprehensive conservation and management strategy in view of catering the planning requirements for the future.
Keywords: EC, Ground water, Pakistan, Rahim Yar Khan, RSC, SAR.

Introduction

The agriculture sector continues to be an essential component of Pakistan's economy. It currently contributes 21 percent to GDP. Agriculture generates productive employment opportunities for 45 percent of the country's labour force and 60 percent of the rural population depends upon this sector for its livelihood (Economic Survey 2011-12).

Pakistan has world largest gravity driven canal irrigation system but due to inadequate maintenance, its efficiency is on continuous decline (Memon and Thapa, 2011). Water is becoming a limiting factor for crop production in many parts of the world, especially developing countries like Pakistan. Current population of Pakistan is 180 million and projected to reach 260 millions by 2025 (Kahlown and Majeed, 2001). Until the beginning of the 1990s, gravity-fed surface irrigation dominated the irrigated agriculture of Pakistan. By the early 1990s, groundwater irrigation had surpassed surface irrigation (Van der Velde and Kijne, 1992). More than 50% of Pakistan's irrigated lands are now served by groundwater wells (Chaudhary *et al.,* 2002). On average, every fourth farming family has a tube well and a large proportion of non-owners purchase groundwater through local, fragmented groundwater markets (Government of Pakistan (GOP), 2000); (Pakistan Water Partnership PWP, 2001) and (Qureshi and Akhtar, 2003). Irrigation water represents an essential input for sustaining agricultural growth in Pakistan's arid to semi-arid climate. Water being the scare resources, optical utilization of the available water resources is most crucial for meeting the growing needs of our rapidly increasing population, while the surface water availability for irrigation has been more or less stagnant for past 30 years; the ground water utilization also appears to have touched the peak is most of the sweet water aquifers. Over explanation of ground water, inequitable distribution; and water quality concerns are the emerging threats. Groundwater is gradually turning saline along with increase in the depth of water table. High pumping costs of groundwater are a limitation towards its use by many small farmers (Shakir *et al.,* 2011). Impact of forthcoming climatic changes on water resources is erratic and country lacks in infra structure to sustain pressure imposed by droughts and floods. Irrigation with low quality water may cause an excessive accumulation of salt in the soil profile that affects the crop yields, quality of produce and the choice of the crop to the grown. In water deficient areas, ground water of low quality is the main sources of irrigation and soil are exposed to salinization hazards. More than 60 % of ground water used on form for irrigation purpose has a water quality for inferior to the canal water. Groundwater salinity increases from head to tail reaches along all irrigation canals including main, secondary and tertiary canals in Pakistan (Latif and Ahmed, 2008). The salinity in the root zone is expected to increase with application of ground water. The ground water irrigation coupled with high pumping cost and salinity hazards make it more important that ground water irrigation be used efficiently and judiciously, agriculturist have increasingly sunk tube wells to keep their business afloat. As the water quality deteriorated, resulting is low per acre yield, farmer turned towards the use of fertilizers and pesticides to sustain their profits.

This paper aims to discuss the difficult and complex challenge of ground water quality management in

Pakistan, review the effectiveness of strategies adopted in the past and suggest future pathways to preserve this precious resource to sustain irrigated agriculture to ensure food security.

Materials and Methods

All the four tehsils (Rahim Yar khan, Sadiq Abad, Khan Pur, Liaqat Pur) of district Rahim Yar Khan were selected for this study. The ground water samples were collected from running tube wells of 122 union councils, 632 villages and 4 tehsils of district Rahim Yar Khan covering four sides (north, east, west and south) of each village within the radius of 1 km of the village. A total of 17337 water samples were collected in plastic bottles and clean bottles were used for sampling purpose. Before sampling, each tube well was allowed to run for at least 20-30 minutes. Labelling was done properly indicating date of sampling and location. The collected water samples were analyzed at Soil & Water Testing Laboratory for Research, Bahawalpur for EC, (Ca +Mg), Na, CO_3, HCO_3 and Cl. Analytical techniques followed during analysis along with instrument make, model and method reference are mentioned in Table 1. Then the sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) were computed by following formulas of U.S. Salinity Lab. Staff (1954). Based on the values of EC, SAR, RSC, water samples were categorized using the international standards (Anonymous, 1954).

$$SAR = \frac{Na}{\{(Ca + Mg)/2\}^{1/2}}$$

$$RSC\ (me\ L^{-1}) = (CO_3^{2-} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$$

Where the concentrations are expressed in milli-equivalents per liter (me L^{-1}) (Richards, 1954).

Table 1. Analysis techniques with references.

Parameters	Technique	Instrument make and model	Method Reference
Electrical Conductivity(EC)	Conductivity meter	CON200 Sensodirect, Lovibond	Richards (1954)
Na and K	Flame photometry	PFP-7, Jenway	Richards (1954)
Ca, Mg, CO_3, Cl and HCO_3	Titrimetric method	-	Richards (1954)

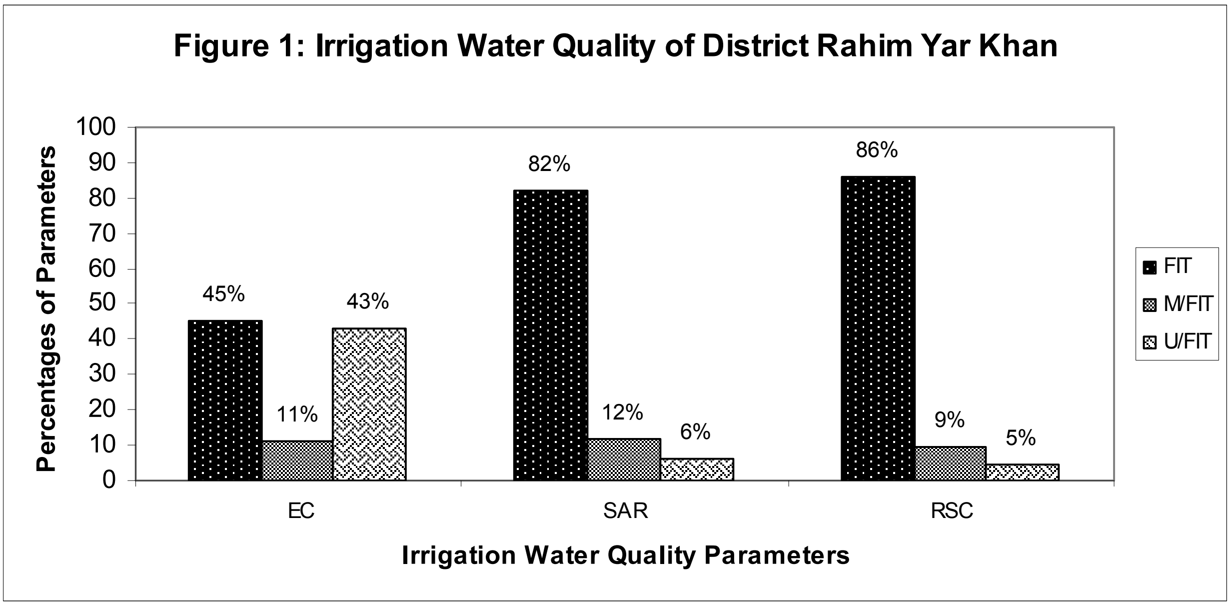
Results and Discussions:

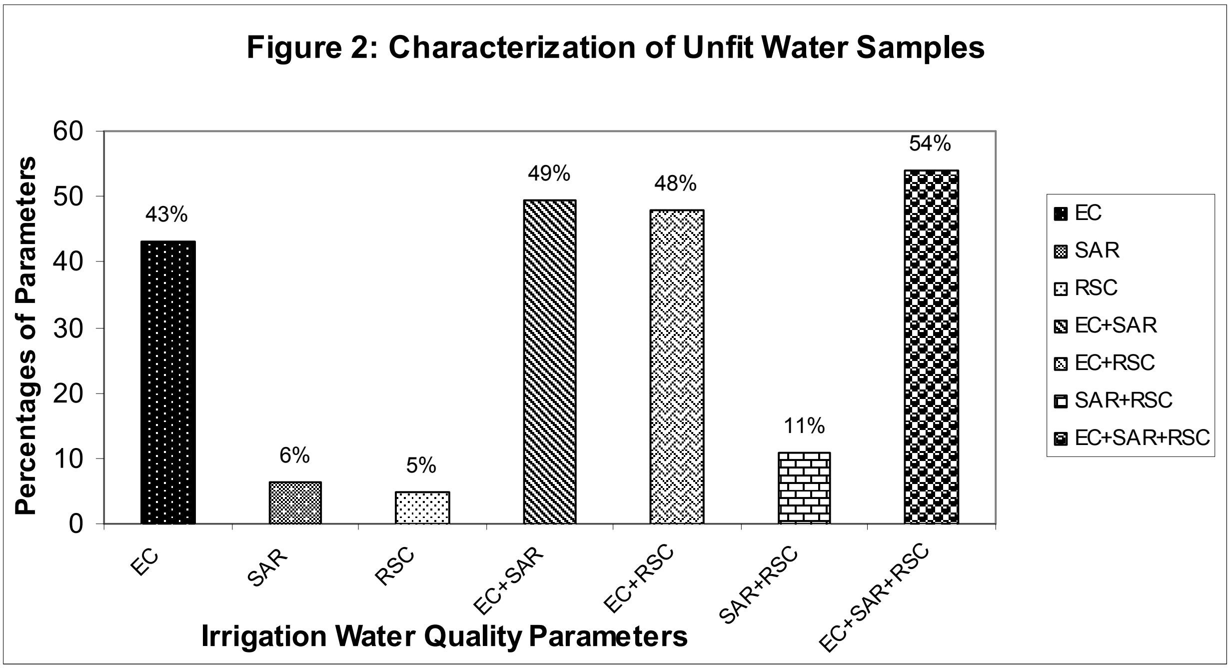
Irrigation water quality parameters of five tehsils of Rahim Yar Khan District are given in Table 2. In this study, water quality was assessed on the criteria given by Soil Fertility Research Institute Punjab (Malik *et al.,* 1984) while others are for comparison purpose. The data was analyzed statistically for mean, standard deviation and percentage following the procedure described by Steel and Torrie (1980). The parameters EC, SAR and RSC were calculated from primary data (*i.e.* EC, (Ca + Mg), CO_3, HCO_3 and Na).

Table 2. Irrigation water quality criteria.

Parameter	Status	Richards,(1954)	WAPDA (1981)	Muhammad (1996)	Malik *et al.* (1984)
EC (µS cm^{-1})	Suitable	750	<1500	<1500	<1000
	Marginal	751-2250	1500-3000	1500-2700	1001-1250
	Unsuitable	>2250	>3000	>2700	>1250
SAR	Suitable	<10	<10	<7.5	<6
	Marginal	10-18	10-18	7.5-15	6-10
	Unsuitable	>18	>18	>15	>10
RSC (me L^{-1})	Suitable	<1.25	<2.5	<2.0	<1.25
	Marginal	1.25-2.50	2.5-5.0	2.0-4.0	1.25-2.5
	Unsuitable	>2.5	>5.0	>4.0	>2.5

Out of total 17337 water samples collected, only 7865 were fit, 1977 were marginally fit and remaining 7495 samples were unfit for irrigation (Figure 1). Most of the samples were unfit due to high EC + SAR + RSC followed by high EC + SAR and EC + RSC (Figure 2).





Electrical Conductivity (µs/cm) Status: Conductivity is a measure of the ability of water to conduct an electric current .Water with high salinity is toxic to plants and poses a salinity hazard. Soils with high levels of total salinity are called saline soils. High concentrations of salt in the soil can result in a "physiological" drought condition. That is, even though the field appears to have plenty of moisture, the plants wilt because the roots are unable to absorb the water. Water salinity is usually measured by the TDS (total dissolved solids) or the EC (electrical conductivity).

Table 3. Range, mean and standard deviation (S.D.) of irrigation quality parameters of ground water, district Rahim Yar Khan, Pakistan.

Parameter	Range	Mean	Standard Deviation
EC (µS cm^{-1})	257-21772	1954.45	1713.20
SAR	0.05-69.78	4.72	3.21
RSC (me L^{-1})	0-5.82	0.42	0.28

The classification of water samples on the basis of EC (Table 4) indicated that EC of 45% water samples were within safe limits (<1000 µs/cm) whereas, 44% samples were unfit (>1250 µs/cm) and 11% were marginally fit (1000-1250 µs/cm) for irrigation. The EC of all water samples ranged from 257-21772 µs/cm with a mean value of 1954.45 µs/cm and standard deviation of 1713.20.

Sodium Adsorption Ratio (SAR) Status: Sodium Adsorption Ratio expresses the relative activity of sodium ions in the exchange reactions with the soil. SAR is representation of sodium hazard. The value of SAR is used to evaluate suitability of water for irrigation. This ratio measures the relative concentration of sodium to calcium and magnesium (Emerson and Baker, 1973). If irrigation water with high SAR is applied to a soil, the sodium in the water can displace the calcium and magnesium in the soil. This will cause a decrease in the ability of the soil to form stable aggregates and loss of soil structure. This will also lead to decrease in permeability and infiltration of the soil to water, leading to problems with crop production (FAO, 1992). Thus in turn soil fertility is damaged because it increases pH and reduces availability of Zn and Fe. Increase in SAR values up to 30 decreases soil aggregate stability (Barzegar *et al.*, 1994). Richards (1954) classified the groundwater based on SAR, the SAR of water samples; mean and standard deviation are given in Table 3.

Table 4. Relative frequency distribution of tube well waters for different irrigation quality characteristics, Rahim Yar Khan, Pakistan.

Parameter	Class interval	Relative freq. distribution		Status
		No. of Sample	(%)	
Electrical conductivity, EC (µS cm^{-1})	<1000	7865	45	Fit
	1001-1250	1977	11	Marginally Fit
	>1250	7495	44	Unfit
Sodium Adsorption Ratio, SAR (m mol $L^{-1})^{1/2}$	<6	14221	82	Fit
	6-10	2039	12	Marginally Fit
	>10	1077	6	Unfit
Residual Sodium Carbonate, RSC (me L^{-1})	<1.25	14891	86	Fit
	1.25-2.50	1634	9	Marginally Fit
	>2.50	812	5	Unfit

The classification of water samples on the basis of SAR (Table 4) indicated that SAR of 82% water samples were within safe limits (<6) whereas, 6% samples were unfit (>10) and 12% were marginally fit (6-10) for irrigation. The SAR of all water samples ranged from 0.05-69.78 with a mean value of 4.72 and standard deviation of 3.21 (Table 3).

Residual Sodium Carbonates (RSC) Status: Residual sodium carbonate (RSC) exists in irrigation water when the carbonate (CO_3) plus bicarbonate (HCO_3) content exceeds the calcium (Ca) plus magnesium (Mg) content of the water. Where the water RSC is high, extended use of that water for irrigation will lead to an accumulation of sodium (Na) in the soil. The results of this include 1) Direct toxicity to crops, 2) Excess soil salinity (EC) and associated poor plant performance, and 3) Where appreciable clay or silt is present in the soil, loss of soil structure and associated decrease in soil permeability.

Table 4 showed the classification of water samples on the basis of RSC. The RSC ranged from 0-5.82 me L^{-1} with mean value of 0.42 and standard deviation of 0.28. Out of 17337 water samples, the RSC of 14891(86%) water samples was within safe limits (<1.25 me L^{-1}). Only 812 water samples (5%) were unfit (>2.50 me L^{-1}) and 1634 (9%) were marginally fit (1.25-2.50 me L^{-1}) due to higher RSC. Waters with high value of RSC can be used by adopting special irrigation and management techniques with regular monitoring of soil salinity status by laboratory analysis (Nishanthiny *et al.,* 2010).

Recommendations

Good quality water, if available, is required for irrigation to supplement tube-well water which will dilute its level of SAR. Other option for amelioration of excessive water (SAR) is through lining of water courses with gypsum stones. Management options for improving high water (RSC) include dilution with canal water and neutralization of carbonate and bicarbonates with the application of acids such as sulfuric acid or acid former such as elemental sulfur. Amendments such as gypsum, press-mud and manure should be applied to reduce the ill effect of ground water on soil. A groundwater regulatory framework should be introduced and implemented for the sustainability of groundwater use. There is need to manage the demand of water and low water delta crops should be preferred to high delta crops. Efficient irrigation methods should be used to irrigate crops and recharge of groundwater should be increased by increasing canal diversions, rainwater harvesting and check dams. Saline water can be used for saline agro-forestry or for alternative agricultural crops and Research on groundwater recharge is urgently required.

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