Quality of Ground Water for Irrigation of Tehsil Kot Adu, District Muzaffar Garh Punjab, Pakistan

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Abstract: Among different factors poor quality of tube well water is the major contributing factor towards the low yield of crops in Pakistan, as it is not fit for irrigation in most of the areas. This study was carried out to provide guidelines to farmers and researchers for better crop production by adopting water management practices. During October, 2010 a total of 315 water samples were collected in collaboration with Agriculture Extension Department from tube wells in tehsil Kot Adu, analyzed and categorized according to the suitability criteria of water quality evaluation. Out of 315 water samples 96(30%) water samples were fit, 25(8%) were marginally fit and 194(62%) were found unfit for irrigation purposes. Out of 194 unfit water samples, 146 unfit water samples (75%) had electrical conductivity higher than permissible limit (i.e. >1250 µS cm^{-1}), 23 samples (12%) were found with high SAR (i.e. >10 $(m\ mol\ L^{-1})^{0.5}$), and 25 samples (13%) had high RSC (i.e. >2.5 me L^{-1}). Further, the analytical data indicated that most of the unfit water samples 146(75%) are unfit due to higher EC followed by EC+RSC 25(13%) and EC+SAR 23(12%). Almost all the area has highly saline water, which is affecting yield of various crops & soil health. Provision of necessary technical assistance to farming communities should be available to guide them at what depth they should extract fresh water instead of saline water. In severally affected areas bio-saline agriculture should be promoted to mitigate ill-effects of salinity hazardous. Cropping pattern should be fairly modified to produce those crops in sensitive areas which are water and salinity resistant.

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1. Introduction

The agriculture sector continues to play a central role in Pakistan's economy. It is the second largest sector, accounting for over 21 percent of GDP, and remains by far the largest employer, absorbing 45 percent of the country's total labor force (Economic Survey 2009-10). To meet the food demand of ever-increasing population of the country and to earn foreign exchange from the agriculture sector, it is essential to enhance agricultural productivity, both through the increase in cropped areas as well as in crop-yields. But limited availability of fresh water and soil salinity/sodicity are the major bottlenecks in the sustainable development of agricultural sector in the country. In arid and semi-arid regions of the world including Pakistan, evapo-transpiration is several times higher than rainfall, which is responsible for net upward movement of salts through capillary action. In Pakistan, the shortfall in irrigation water requirement is likely to reach 107 MAF by 2013. In order to supplement the present canal water availability at farm-gate (43 MAF), more than 531,000 tube wells are pumping 55 MAF in Pakistan. Estimates show that about 70–80% of tube well water in Pakistan is unfit for irrigation. It is estimated development of surface salinity and/or sodicity on an area of about 3 × 106 ha in the country as a result of using marginal-quality drainage and groundwater without appropriate management practices. Unfortunately, canal water is not sufficient to exploit the potential of soil and crop cultivars under intensive cropping system. The scarcity of good quality surface water is becoming more acute day by day therefore; one has to rely on irrigation through tube wells. To increase the productivity of agricultural sector, abandoned land and marginal-quality groundwater will have to be managed. Pakistan's groundwater aquifer consists of join layers of fresh and saline waters and the proportional percentage of these layers varies from place to place. The bio - saline technology is to be promoted. The investment will be required in future adoption of biosaline agricultural technology (Economic Survey 2009-10). The situation of groundwater-quality is deteriorating fast, due to rapid growth of tube wells in the private sector. In Punjab alone, the number of private tube wells has increased from about ten thousand in 1960 to about five hundred thousand in 2000. These ground waters have different types of salts, which deteriorate the soil accordingly (Masood and Gohar, 2000). Unfortunately, about 50-60 % of discharge of existing wells is brackish in nature (Ashfaq *et al*., 2009) that requires interventions for sustainable land use. According to another estimate, 25 percent of tube well discharge in the Punjab province is useable, while 25% and 50% is marginal and unfit, respectively, for irrigation (Ashfaq *et al*., 2009). Ali *et al.* (2009) reported that quality of available ground water in most (76.6%) of the villages of Lahore district was not suitable for sustainable crop production and soil health. According to Soil Fertility Survey and Soil Testing Institute, Rawalpindi (2006-07), 73% of water samples analyzed, were fit for irrigation during 2006-07. A water quality study has shown that out of 560,000 tube wells in Indus Basin, about 70 percent are pumping sodic water which in turn is affecting the soil health and crop yield (Kahlown *et al.*, 2003). In an other study by Zahid *et al*. (2003) out of 680 water samples, 33 percent were fit, 19 percent were marginally fit and the rest of 48 percent were unfit. Rizwan *et al.* (2003) reported the ground water quality for irrigation in Rawalpindi district. Out of 96 water samples, 71 percent were fit, 9 were marginally fit and 20 percent were found unfit for irrigation. Khalid *et al*. (2003) reported that in Rawalpindi district, 71% of water samples were fit, 9% marginally fit and 20% were unfit for irrigation. Similarly, 48 percent of the water samples in Gujrat (Zahid *et al*., 2003) and 20 percent in Rawalpindi (Rizwan *et al*., 2003) were unfit for irrigation. According to Shakir *et al.* (2002), 64 water samples were collected from new tubewell bores from various locations of District Kasur to check the quality of under ground water for irrigation purpose. The results showed that electrical conductivity of the samples varied from 524 to 5700 $\mu S\ cm^{-1}$, sodium adsorption ratio of the samples ranged from 0.49 to 26.00 while residual sodium carbonate ranged from zero to 17.00 me L^{-1}. Out of 64 samples, 26 samples were fit, 8 were marginally fit and 30 samples were found unfit for irrigation. The sodic groundwater containing high amount of sodium, carbonates and bicarbonates enhances sodicity in soil, deteriorates the soil-permeability and hydraulic conductivity of soil (Haider *et al*. 1976, Ghafoor *et al*. 1997). Thus, it was very important to ascertain the quality of underground water used for irrigation. Voluminous work has been done for Punjab but very little information is available at district/ tehsil/ union council level. More over information available regarding the quality of tube well water are general (fit, marginally fit and unfit) and no comprehensive study has been made. The objective of this study was to monitor the quality of water of tube wells of 32 union councils of tehsil Kot Adu and to find out the extent of various parameters contributing individually or collectively to the quality of tube well water.

Table 1. Quality of Tube well Water Samples Punjab, Pakistan

Status	No. of Samples	Percentage
Fit	18605	45
Unfit	22529	55
Unfit due to:		
EC	10547	47
SAR	2479	11
RSC	9503	42

Source: Soil Fertility Research Institute, Punjab, 1981-96

2. Methodology

During October 2010, a total of 315 tube well water samples were collected from 32 union council of tehsil Kot Adu, district Muzaffar Garh in collaboration with the Agriculture Extension Department, Kot Adu. Tubewells selection was made randomly in tehsil. The samples were taken in polythene bottles after thirty minutes of tubewell operation. The depth of tubewells ranged from 60 to 120 feets. The tubewells water is being used for raising crops, vegetables, ornamental plants, forests trees and nurseries. The water samples were analyzed at Soil and Water Testing Laboratory Muzaffar Garh for electrical conductivity (EC), cations (Ca^{+2} + Mg^{+2}, Na^{+}) and anions (CO_3^{-2}, HCO_3^{-}, Cl^{-}) by the methods described by Page *et al.* (1982) and U.S. Salinity Lab. Staff (1954). Residual sodium carbonates (RSC) and sodium adsorption ratio (SAR) were determined by following formulas of U.S. Salinity Lab. Staff (1954).

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

$$SAR = Na^{+} / \sqrt{Ca^{++} + Mg^{+}}/2$$

The criterion used for evaluation of irrigation water was proposed by Malik *et al*. (1984) and is given in Table 2.

Table 2. Irrigation Water Quality Criteria

Parameter	Status	Richards, L.A. (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
Cl (me L^{-1})	Suitable	<4.5	-	0-3.9	-
	Marginal	-	-	-	-
	Unsuitable	>4.5	-	>3.9	-

3. Results and discussion

Irrigation water quality parameters of 32 union councils of Tehsil Kot Adu 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 TSS, SAR and RSC were calculated from primary data (i.e. EC, Ca + Mg, CO_3, HCO_3 and Na).

Out of 315 water samples 96(30%) water samples were fit, 25(8%) were marginally fit and 194(62%) were found unfit for irrigation purposes. Out of 194 unfit water samples, 146 unfit water samples (75%) had electrical conductivity higher than permissible limit (i.e. >1250 µS cm^{-1}), 23 samples (12%) were found with high SAR (i.e. >10 (m mol L^{-1})$^{0.5}$), and 25 samples (13%) had high RSC (i.e. >2.5 me L^{-1}). Further, the analytical data indicated that most of the unfit water samples 146(75%) are unfit due to higher EC followed by EC+RSC 25(13%) and EC+SAR 23(12%).

3.1 Ionic concentration

Among cations, Na^+ was the dominant ranging from 0.17 to 67.9 me L^{-1} with mean value of 9.66 me L^{-1} followed by Ca^{+2} + Mg^{+2} with mean value of 7.52 me L^{-1} (Table 2). Among the anions, HCO_3^- was the dominant anion ranging from 1.3-13.2 me L^{-1} with mean value of 6.04 me L^{-1} followed by Cl^- with mean value of 5.59 me L^{-1}. However, CO_3^{-2} were present in few water samples.

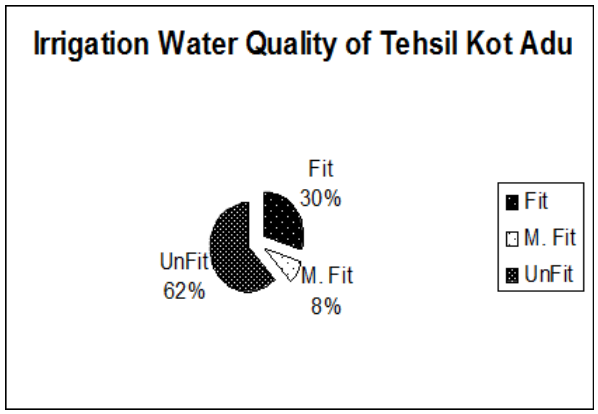

Figure 1. Irrigation Water Quality of Tehsil Kot Adu

3.2 Electrical conductivity (EC)

A measure of water salinity that is important for crop yield is Electrical Conductivity (EC), which increases the concentration of soluble salts in soil, therefore, the primary effect of high EC water on crop productivity is the inability of the plant to compete with ions in the soil solution for water (physiological drought). The higher the EC, the less water is available to plants, even though the soil may appear wet, because plants can only transpire pure water and usable plant water in the soil solution decreases dramatically as EC increases. Electrical conductivity of water samples ranged from 336 to 8500 µS cm^{-1} with mean of 1713 µS cm^{-1} and standard deviation of 1094 µS cm^{-1}. 146 unfit water samples (75%) had electrical conductivity higher than permissible limit (i.e. >1250 µS cm^{-1}). Irrigation water contains a mixture of naturally occurring salts. The extent to which the salts accumulate in the soil will depend upon the irrigation water quality, irrigation management and the adequacy of drainage. Salinity control becomes more difficult as water quality becomes poorer. As water salinity increases greater care must be taken to leach salts out of the root zone before their accumulation reaches at concentration which might affect yield. Water for irrigation generally classified as saline or unsuitable can be used successfully to grow crops without long-term hazardous consequences to crops or soils, with the use of improved farming and management practices (FAO, 1992).

Table 2. Range, mean and standard deviation (S.D.) of irrigation quality parameters of ground water, Kot Adu

Parameter	Range	Mean	Standard Deviation
EC (µS cm^{-1})	336-8500	1713	1094
SAR	0-166	5.58	9.88
RSC (me L^{-1})	0-10.3	1.22	2.06
Ca+Mg	2.3-25.75	7.52	3.68
Na	0.17-67.9	9.66	8.38
CO3	0-3.8	0.68	1.02
HCO3	1.3-13.2	6.04	2.47
Cl	0.5-52.5	5.59	5.36
SO4	0-37.6	4.86	5.50

3.3 Sodium adsorption ratio (SAR)

It represents the relative proportion of Na to Ca + Mg. The sodium hazard is typically expressed as the sodium adsorption ratio (SAR). Calcium will flocculate, while sodium disperses soil particles. This dispersed soil will readily crust and have water infiltration and permeability problems. The SAR of water samples ranged from 0.00 to 166 with mean of 5.58 and standard deviation of 9.88 (Table 2). 23 samples (12%) were found with high SAR (i.e. >10 (m mol $L^{-1})^{0.5}$). Sodium adsorption is stimulated when Na proportion increases as compared to Ca + Mg resulting in soil dispersion (Emerson and Bakker, 1973). At high levels of sodium relative to divalent cations in the soil solution, clay minerals in soils tend to swell and disperse and aggregates tend to slake, especially under conditions of low total salt concentration and high pH. As a result, the permeability of the soil is reduced and the surface becomes more crusted and compacted under such conditions. Soil's ability to transmit water is severely reduced by excessive sodicity (FAO, 1992).

3.4 Residual sodium carbonate (RSC)

The irrigation water containing excess of CO_3 and HCO_3 will precipitate calcium and hence sodium will increase in soil solution. It leads to saturation of clay complex with sodium and consequently decreased infiltration rate. The RSC values of water samples ranged from 0 to 10.3 me L^{-1} with mean of 1.22 me L^{-1} and standard deviation of 2.06 (Table 2). 25 samples (13%) had high RSC (i.e. >2.5 me L^{-1}).

4. Discussion and Recommendations

Water used for irrigation can vary greatly in quality depending upon type and quantity of dissolved salts. Salts are present in irrigation water in relatively small but significant amounts. They originate from dissolution of weathering of the rocks and soil, including dissolution of lime, gypsum and other slowly dissolved soil minerals. The suitability of water for irrigation is determined not only by the total amount of salts present but also by the kind of salts. Water quality or suitability for use is judged on the potential severity of problems that can be expected to develop during long-term use. The problems that result vary in both kind and degree and are modified by soil, climate and crop, as well as by the skill and knowledge of the water user. The soil problems most commonly encountered and used as a basis to evaluate water quality are those related to salinity, water infiltration rate, specific ion toxicity and a group of other miscellaneous problems (Ayers and Westcot, 1994).

An integrated, holistic approach is needed to conserve water and prevent soil salinization and water logging while protecting the environment and ecology. Firstly, source control through the implementation of

more efficient irrigation systems and practices should be undertaken to minimize water application and reduce deep percolation. Conjunctive use of saline groundwater and surface water should also be undertaken to aid in lowering water table elevations, hence to reduce the need for drainage and its disposal, and to conserve water (FAO, 1992). Efficiency of irrigation must be increased by the adoption of appropriate management strategies, systems and practices and through education and training. There is usually no single way to achieve salinity control in irrigated lands and associated waters. Many different approaches and practices can be combined into satisfactory control systems. The appropriate combination depends upon economic, climatic and social as well as hydro-geologic situations (FAO, 1992). It was observed that most of the water samples were unfit due to higher electrical conductivity indicating no sodicity problem in these waters.
However, the effect of different qualities of water on soil health and crop yield is also governed by the type of soil, climate and management practices (Singh et al., 1992). It is therefore, important to point out that waters having EC up to 1.25 dS m^{-1} may be used to raise most of the crops on light textured soils without affecting soil quality (Pervaiz *et al.,* 2003). However, the use of unfit water due to high EC will cause salinization. To avoid salinzation, it was proposed to increase/decrease the depth of bore to find good quality water (Yonus, 1977). The farmers can use marginal and unfit water for salt tolerant crops (wheat, sorghum and barley) and fruit (Guava) trees etc. It is also recommended that on degraded soils, the poor quality irrigation water may be used to grow *Eucalyptus* and *Acacia* for timber and fuel, and *Atriplex spp*. for grazing purposes. However, quality of irrigation water in most of the union councils of Tehsil Kot Adu is still suitable for raising crops and orchards.

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