Characterization of Ground Water Quality for Irrigation in Tehsil and District Layyah, Punjab Pakistan

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Abstract: Water quality assesment through analysis is pre requisite for its better utilization by crops as it is essential for the maintainance of turgidity, absorption of nutrients and metabolic process of plants. Direct use of unfit irrigation water not only causes severe salinity/sodicity problems in soil but also depress plant growth to alarming level depending upon the extent of dissolved salts. A total of 296 advisory water samples were received/collected from tehsil Layyah during previous three years (2009-10 to 2011-12) , analyzed and categorized according to the suitability criteria of water quality evaluation. Out of 296 water samples, 114(38%) water samples were fit, 79(27%) were marginally fit and 103(35%) were found unfit for irrigation purposes. The analysis data showed that, 95 unfit water samples had electrical conductivity higher than permissible limit (i.e. >1250 µS cm^{-1}), 12 samples were found with high SAR (i.e. >10 (m mol $L^{-1})^{0.5}$), and 47 samples had high RSC (i.e. >2.5 me L^{-1}). It can be inferred from data that quality of available ground water in most of the cases is suitable for sustainable crop production and soil health. Guidelines to use these water for irrigation purposes should be based on the soil texture for its best utiliztion and avoid any harmful effects on soil health. 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. Adoption of bio-saline agriculture, addition of farmyard manure/green manure, sheep, goat and fish farming might add to the farmer's income under these condition.

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1. 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). Water productivity in agriculture, which is often used as a criterion for decision-making on crop-production and water-management strategies, is severely constrained by salinity of land as well as of water. Salinity of water is more common than that of the land and it is often the cause of salinity development in soils, largely because of the misuse of salty water for crop production. There are two major approaches to improving and sustaining productivity in a saline environment: modifying the environment to suit the plant and modifying the plant to suit the environment. Both these approaches have been used, either singly or in combination (Tyagi and Sharma, 2000), but the first approach has been used more extensively because it enables the plants to respond better not only to water but also to other production inputs. Groundwater is a natural resource and is a kind of reuse of surface water lost during its conveyance and application phases. Groundwater quality is better if the recharge source is nearby such as rivers, canals, ponds or irrigated fields. 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). M.B Khan *et al.* (2012) reported that in tehsil Kot Adu, District Muzaffar Garh, 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}). 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

Table 1. 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	-

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 tubewells 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 µS 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 level. The objective of present study was to assess the quality of groundwater in the tehsil and district Layyah for its suitability to irrigation.

2. Material and Methods

During previous three years (2009-10 to 2011-12), a total of 296 advisory water samples were received/collected from tehsil Layyah. The samples were taken in polythene bottles after thirty minutes of tubewell operation. The depth of tubewells ranged from 25 to 180 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 Layyah 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).

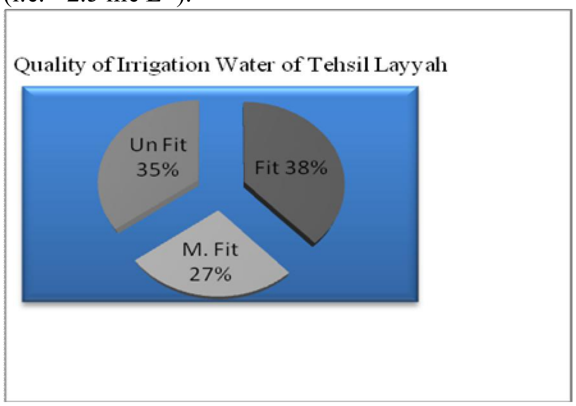
$$RSC\ (meq\ L^{-1}) = (CO_3^{-2} + HCO_3^{-}) - (Ca^{++} + Mg^{+})$$

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

The criteria used for evaluation of irrigation water was proposed by Malik *et al.* (1984) and is given in Table 1.

3. Results

Irrigation water quality parameters of Tehsil Layyah 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 296 water samples, 114(38%) water samples were fit, 79(27%) were marginally fit and 103(35%) were found unfit for irrigation purposes. The analysis data showed that, 95 unfit water samples had electrical conductivity higher than permissible limit (i.e. >1250 µS cm^{-1}), 12 samples were found with high SAR (i.e. >10 (m mol $L^{-1})^{0.5}$), and 47 samples had high RSC (i.e. >2.5 me L^{-1}).



3.1 Ionic concentration

Among cations, Ca^{+2} + Mg^{+2} were the dominant ranging from 0.23 to 391 me L^{-1} with mean value of 7.08 me L^{-1} followed by Na^{+} with mean value of 5.88 me L^{-1} (Table 2). Among the anions, HCO_3^- was the dominant anion ranging from 0.18-30.75 me L^{-1} with mean value of 6.14 me L^{-1} followed by Cl^- with mean value of 4.71 me L^{-1}. However, CO_3^{-2} were present in few water samples.

3.2 Electrical conductivity (EC)

Irrigation water contains a mixture of naturally occurring salts. The extent to which the salts accumulated in the soil would depend upon the irrigation water quality, irrigation management and the adequacy of drainage. Salinity control was become more difficult as water quality become poorer. As water salinity increased, greater care must be taken to leach salts out of the root zone before their accumulation reached at concentration which might affect yield (FAO, 1992). These salts are measurable by Electrical Conductivity meter. Results showed that the EC of the water samples ranged from 312 to 4010 with mean value of 1167µS cm^{-1} (Table 2). The analysis data showed that, 95 unfit water samples had electrical conductivity higher than permissible limit (i.e. >1250 µS cm^{-1}). Samples showing high EC would cause salinity problem. It could be used by mixing with good quality water in the ratio of 2: 1 (two parts of tube well water and one part of good quality water). Salt tolerant crops including wheat, maize, carrot, onion, barely etc could be cultivated. Occasional flushing of the soil profile with heavy irrigation to reduce the salt concentration in the root zone, scheduling of irrigations (i.e. increasing the number of irrigation by reducing the amount of water per irrigation keeping the total delta of water for the crop same) might help to reduce the problem of salinity with the use of saline water.

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 0.1 to 26.15 with mean of 3.70 and standard deviation of 3.26 (Table 2). 12 samples 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 19.57 me L^{-1} with mean of 1.27 me L^{-1} and standard deviation of 2.43 (Table 2). 47 samples had high RSC (i.e. >2.5 me L^{-1}).

Table 2. Range, mean and standard deviation (S.D.).

Parameter	Range	Mean	Standard Deviation
EC (µS cm^{-1})	312-4010	1167	534
SAR	0.1-26.15	3.70	3.26
RSC (me L^{-1})	0-19.57	1.28	2.43
Ca+Mg	0.23-391	7.08	22.47
Na	0.13-28.02	5.88	4.58
CO3	0-2.72	0.14	0.37
HCO3	0.18-30.75	6.14	3.08
Cl	0-32.5	4.71	3.62
SO4	0-6.04	0.72	1.01

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).

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 (Waheed *et al.,* 2010). Adoption of bio-saline agriculture, addition of farmyard manure/green manure, sheep, goat and fish farming might add to the farmer's income under-

these conditions (Pervaiz *et al.,* 2003). However, quality of irrigation water in most of tehsil Layyah is still suitable for raising crops and orchards.

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