

**Original Research Article**

**Quality Assessment of Tubewell Water for  
Irrigation and Impact on Soil and Crops in  
Central Punjab, Pakistan**

**ABSTRACT**

The study was carried out to assess the quality of tubewell (TW) waters for irrigation and their effects on soils and crops. A total of 529 TW water samples from 261 villages were randomly collected from Lower Bari Doab Canal (LBDC) command of district Sahiwal in Central Punjab of Pakistan during 2012 and 2013. Composite surface soil samples along with yields of crops were collected from fields irrigated with TW and canal waters (CW). Soils were analysed for pHs, E<sub>ce</sub>, and water samples for EC, cations, anions and then RSC and SAR were computed. It was observed that 71% TW waters were saline and about 20% were sodic in nature and were not suitable for irrigation purpose. The concentrations of chemical constituents in water from the LBDC aquifer system vary both depth and location wise. It was estimated that sufficient amount of soluble salts were added to soil with the irrigation of these TW waters which significantly imparted negative effects on soil quality resulting into reduction of yields of various crops up to 15%.

*Keywords: Tubewell water quality; Soil quality; crop yield; EC; SAR; RSC.*

## 1. INTRODUCTION

Water quality is an important factor when considering an irrigation programme. The common water quality parameters are electrical conductivity (EC), sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) [1]. The canal water supply is not sufficient to meet the water requirement of the crops raised under intensive cropping system of Punjab, Pakistan. Hence, farmers are forced to meet this deficit through tube wells water which, over 70% is of poor quality [2, 3].

Soluble salts in irrigation water, if present in sufficient quantity, affect soil quality and crops yields. Soil degradation has been defined as a reduction in soil quality in response to natural or anthropogenic causes, in a manner, that reduces current or potential productivity [4]. Soil degradation reduces the productivity of soil and water resources in many areas of the world, causing reductions in crop yields, higher production costs, and lower net income from agriculture. The economic impacts of soil degradation might be moderate when viewed from global perspective, but the impacts are severe in selected areas. [5]. Policy reforms and public investments are needed in those areas to reduce soil degradation, improve rural income, and enhance food security [6]. The most severe aspect of soil degradation on Asian lands is soil salinity that has occurred through the accumulation of salts, mainly deposited from saline irrigation water or through mismanagement of available water resources [7]. The historical lands of Iran, Pakistan, Afghanistan, India and China are also subject to ancient and ongoing soil degradation processes which are subtle in some areas but evident and drastic in others.

The effect of different water qualities on soil health and crop yield is governed by many factors including water quality (amount and kind of salts), soil texture, crop species, climate (rainfall and temperature) and management practices. [8,9]. The results of a long term study of the effects of TW of EC  $2.40 \text{ dSm}^{-1}$  and SAR  $9.20 (\text{m mole L}^{-1})^{0.5}$  on soil properties showed that soil EC increased from  $2.98$  to  $4.55 \text{ dSm}^{-1}$  and SAR increased from  $10.8$  to  $18.9 (\text{m mole L}^{-1})^{0.5}$  after 7 years [9]. Similar results have been reported by other [10]. The negative effects of brackish water on the yields of wheat grain, paddy, berseem, maize fodder [9, 11] and sunflower [12] have been reported. The wheat grain yield from field irrigated with TW was found to be more affected by the sodicity compared with salinity of water [13].

Little attention is paid by farming community to keep the land productive in Pakistan. The pre-requisite for the safe use of poor quality water is to know the amount and kind of salts in irrigation water. Limited data on the quality status of TW waters in Lahore [14], Kasur [15], Gujarat [16], Rawalpindi [17], Jhang [13], Sahiwal [3] and other districts of Punjab is available. But systematic and comprehensive information on TW water quality and its implications on soil and crop productivity are not sufficient in the south Punjab of Pakistan. Therefore, a detailed survey of district Sahiwal was carried to collect TW water and soil samples along with yields data of crops grown in the area. The detailed information on ionic

concentrations of water samples at village levels and remedial measures for the safe use of brackish water has been submitted elsewhere. In this report we will discuss (i) overall quality status of TW waters for irrigation and, (ii) quantification the effect of TW water irrigation on soil quality and some selected crops yields in the study area.

## **2. METHODOLOGY**

### **2.1. Description of Study area**

Sahiwal district (30°39'52"N 73°6'30"E) occupies central part of Punjab Province, Pakistan, and situated in a semiarid region that is flood irrigated with canal and tubewell waters. The parent material is alluvium formed by the Ravi and Sukh Bias rivers. It is highly productive and texture varies from silt loam to clay loam and clay type. Saline-sodic soils also exist in the district. The major crops grown are cotton, rice, and maize, sugar cane in Kharif and wheat and potato in Rabi season with cropping intensity > 200%. The annual rainfall ranges from 150 to 200 mm. The average maximum temperature during summer usually remains 40-45 °C. The winter is cold and dry and the average minimum temperature is 4-5 °C during month of January.

### **2.2. Sampling**

Out of 531 villages of Sahiwal district, 261 villages were randomly sampled for 529 TW in Canal Command Area (CCA) during 2012 and 2013 (Fig. 1). The CCA comprised of nine distributaries of Lower Bari Doab Canal (LBDC); four on right side (RD) namely, 4R, 5R, 6R and 7R; five on left side (LD) namely, 5L, 9L, 11L, 12L and 14L. Out of total 261, 105 villages were sampled from RD and 156 from LD. The samples were collected in plastic bottle after 30 minutes of TW operation. The depths of TW ranged from 61 to 152 m. Twenty composite soil samples, 10 from each Chichawatni and Sahiwal tehsils, were collected from 0 to 15 cm from the selected farmer fields irrigated with TW and CW to monitor the effect of poor quality water on soil health.

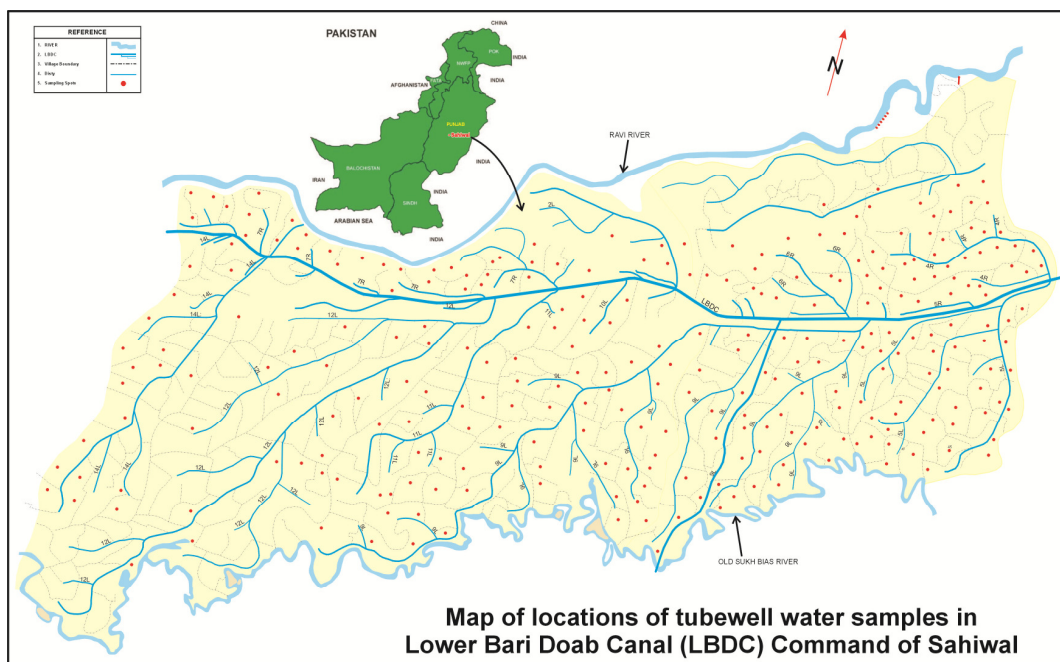


Fig. 1 Map showing locations of tubewell water samples in LBDC command of Sahiwal district.

### 2.3. Soil and Water Analyses

The analytical work was carried out at Soil and Water Testing Laboratory, Sahiwal. Soil samples were air-dried, ground and passed through 2 mm sieve and preserved in plastic bottles for analyses. Soils were analysed for pH<sub>s</sub>, electrical conductivity of the saturated paste (EC<sub>e</sub>), and water samples were analysed for EC, cations (Ca<sup>2+</sup> + Mg<sup>2+</sup>, Na<sup>+</sup>) and anions (CO<sub>3</sub><sup>2-</sup>, HCO<sub>3</sub><sup>-</sup>) by methods described by [18]. The criterion for the suitability of irrigation water and procedures to calculate the RSC and SAR were used accordingly [1].

### 2.4. Estimation of Soluble Salts Addition to Soil with TW Water Irrigation

The quantities of soluble salts added into soil with the irrigation of TW of different qualities in the study area were estimated [19] to assess their effects on soil quality. Total dissolved salts (TDS) of TW ranged from 218 to 3309 mg L<sup>-1</sup> in the area and these values were used to estimate the amount of salts added to soil with the irrigation of these TW. The consumptive use of water by wheat, cotton, rice, maize, and potato crops [20] was used to estimate the salts addition into soil under prevailing crop rotations and value of TDS used was 3309 mg L<sup>-1</sup>.

### 2.5. Crop Yield Data and Statistical analysis

The yield data of wheat, cotton, maize and potato crops were recorded, according to the standard procedures, from 10 farmer's fields from each tehsil irrigated with CW and TW to compare the effects of brackish water on the yields. The comparisons among the treatment means were made by calculating standard error of the mean values [21].

## 3. RESULTS AND DISCUSSION

### 3.1. Quality Status of Tubewell Waters of District Sahiwal

Data (Fig.2) on characterization of TW water samples based on EC, RSC and SAR showed that 71% TW were saline and >20% samples were sodic in nature[13,14,15]. The quality of TW water in RD was comparatively better than in LD due to its location between LBDC and Ravi River. The TW situated along LBDC had sweet water due to the seepage of CW. The more TW water samples on LD were brackish than RD and about 6% of the total TW samples had extreme values of EC, RSC and SAR. The use of such waters caused soil salinity and affected crops yields. The yields reductions were not to that extent because of sandy aquifer without any marked clay layers [22], use of flood irrigation of TW with dilution of CW and sowing of semi tolerant crop like wheat. Based on soil and water analyses, the farmers were advised proper management strategies for sustainable crop production. It was realized that those farmers who followed the departmental recommendations were harvested good yields.

The concentrations of chemical constituents in water from the LBDC aquifer system vary both depth and location wise. The deep groundwater quality investigations carried out by [23] showed that the distribution of saline and fresh groundwater zones in Bari Doab is a result of past and present hydrologic, climatic, and topographic factors. Among these, the present and former positions of stream channels, representing sources of recharge, the high bluffs of the bar uplands in the upper part of the Bari Doab, and differences in the permeability within the alluvial aquifer are the most important.

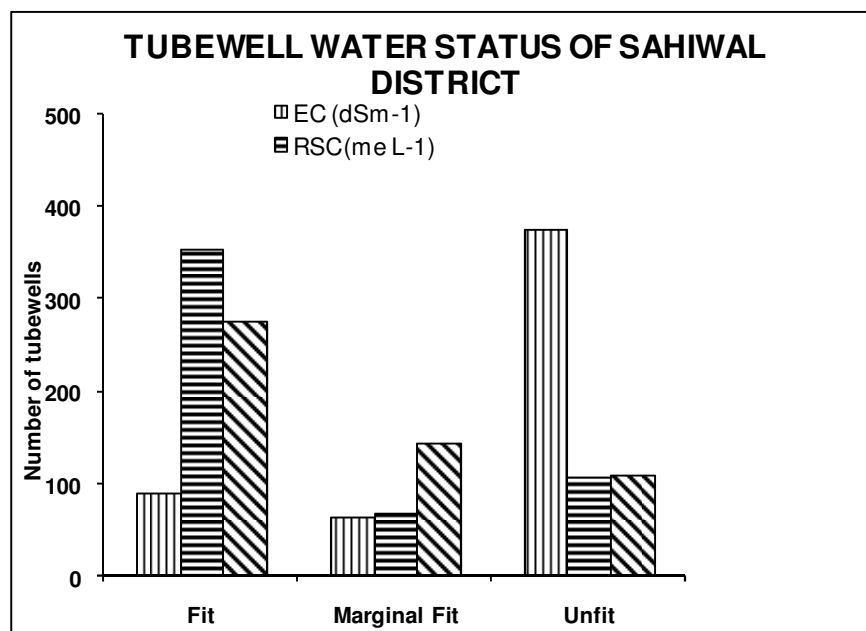


Fig.2. Characterization of tube well waters (n=529) on the basis of EC, RSC and SAR of district Sahiwal.

### 3.2. Impact of Tubewell Waters Irrigation on Soil Quality

The farmers of district Sahiwal used poor quality TW waters having EC 0.34 - 5.17 dSm<sup>-1</sup> with SD 0.88 (TDS ranged from 218 to 33000 mg L<sup>-1</sup>) for crop production due to the scarcity of CW. The use of these water qualities contributed to the soil salinity [24] leading to soil degradation. It was estimated that a huge amount of salts were added into soil with the application of 0.30 m irrigation water of different qualities (Fig. 3). Similarly, it was calculated that 96 t ha<sup>-1</sup> soluble salts were deposited in soil under maize-potato-maize cropping sequence with the application of TW having EC 5.17dSm<sup>-1</sup> (Fig. 4).

The effects of brackish irrigation water on soil salinity due to continuous use of poor quality TW was evaluated at farmer's field in two tehsils of district Sahiwal during 2011 and 2012. The EC of TW used for irrigation ranged from 1.00 to 3.62 dSm<sup>-1</sup>. It was observed that soil EC increased from 2.06 to 3.62 dSm<sup>-1</sup> in Chichawatni and 2.40 to 3.97 dSm<sup>-1</sup> in Sahiwal tehsil with continues use of TW. This data supported that substantial amounts of soluble salts were added to soils with the application poor quality TW irrigation as given in Fig. 3 and 4. However, the increase in soil salinity was not to that extent as it was expected. This was due to leaching of salts with the application of heavy flood irrigations by the farmers, light to medium textured soils and rainfall during the rainy season [3]. It means the significance of rainfall and leaching fraction in maintaining the soil health while using brackish water should be duly accounted for [8]. Similarly, the results of a long term study conducted on the effects of brackish TW on soil quality showed that after growing 12 crops following berseem-rice-

wheat- maize fodder-berseem crop rotation, the non-saline and non-sodic soil was converted to sodic soil (SAR 18.9) by the use of TW [9]. Similar results were also reported by others [10, 24].

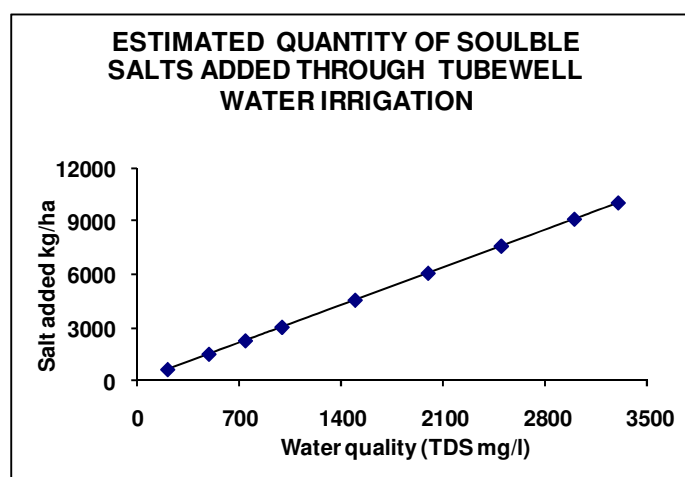


Fig.3. Estimation of the amount of soluble salts added to soil through tubewell waters irrigation of 0.30 m depth of TDS 218 to 3300 mg L<sup>-1</sup>

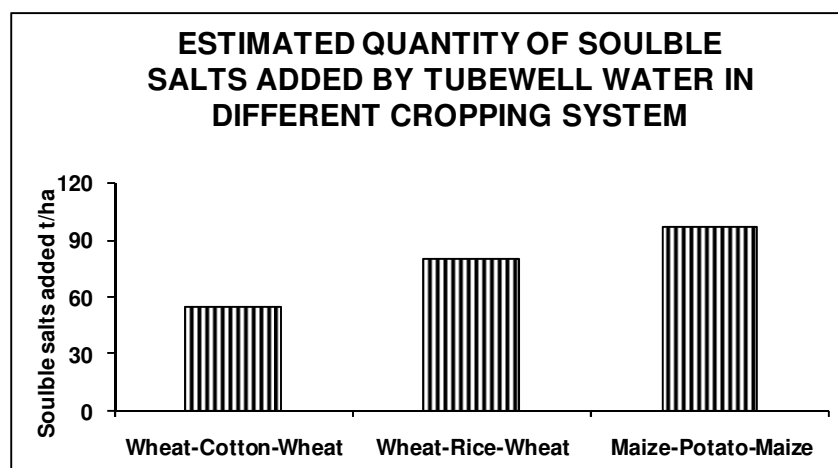


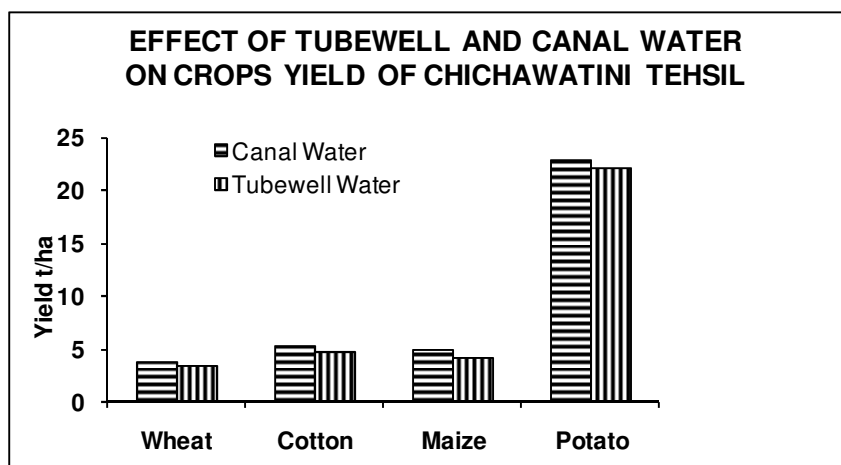
Fig.4. Estimation of the amount of soluble salts added to soil with tubewell water (EC 5.17 dSm<sup>-1</sup>) under different cropping systems of district Sahiwal.

### 3.3. Impact of Tubewell Water Irrigation on Crop Yield

The effect of water quality on the yields of wheat, cotton, maize and potato crops was evaluated at farmer's fields of Chichawatni and Sahiwal tehsils of the district (Fig. 5). The yields of crops reduced from 3 to 15% in the fields where usually TW was used compared to CW irrigated plots. The yields of crops were not severely affected by TW water having

EC up to  $5.17 \text{ dS m}^{-1}$  in LD because the lithologic logs of bore holes have shown sandy aquifer without any marked clay layers[22] and also due to the management practices adopted by the farmers[25]. It was noted during survey that the farmers harvested optimum yields of crops with brackish TW following viable management practices. For example, the addition of farm manures, use of balanced fertilizer, proper type of fertilizers (use of single supper phosphate on sodic soils) and light irrigation of poor quality water proved better. Furthermore, the response of crops to different water qualities differed greatly due to different salt tolerance limits of salts by crops [26]. The use of brackish TW water ( $\text{EC } 2.40 \text{ dSm}^{-1}$ ;  $\text{SAR } 9.20 (\text{mmol L}^{-1})^{0.5}$ ;  $\text{RSC } 5.70 \text{ me L}^{-1}$ ) on crops grown under berseem-rice-wheat-maize fodder-berseem rotation on permanent layout during 1987-88 to 1993-94 reduced crops yields from 3 to 36% over CW [9]. Similar results were also reported by others [10, 25]. The soluble salts exerted both general and specific effects on plants which reduced crops yields.

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Fig.5. Effect of water quality on the yields of crops at farmer's fields. EC of TW ranged from  $1.00$  to  $2.82 \text{ dS m}^{-1}$  in Chichawatni and  $1.12$  to  $3.62 \text{ dS m}^{-1}$  in Sahiwal.

## 4. Conclusion

Data on quality status showed that more than 71% TW were saline and >20% were saline or sodic in nature. The concentrations of chemical constituents in water from the LBDC aquifer system vary both depth and location wise. It was estimated that application of TW irrigation having different salinities added substantial amount of soluble salts into soil that affected the soil quality. Resultantly, the yields of different crops reduced from 3 to 15% with the continuous use of poor quality irrigation water. The use of poor quality TW for irrigation had serious consequences for sustainability of soil and crop productivity in the country.

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