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IRRIGATION QUALITY OF UNDERGROUND WATER IN DISTRICT MULTAN

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ABSTRACT

Water is the basic resource for agricultural production to provide food and feed to humans and livestock and ultimately to livelihood of the people. The productivity of agricultural crop depends on water quality. The irrigation water containing hazardous and higher concentrations of salts affects the crop yield to a far greater extent than any other environmental factors. Therefore, a field survey was conducted in three tahsils of Multan to determine the quality of underground water being pumped. In total, of 2686 water samples were collected. The water samples were analyzed for their salt constituents. Data for quality of irrigation were categorized, from electrical conductivity (EC) point of view : fit [(EC < 1000 µS cm^{-1}), marginally fit (EC = 1000-1250 µS cm^{-1}) and unfit (EC > 1250 µS cm^{-1})]; from residual sodium carbonate (RSC) point of view, fit (RSC < 1.25 me L^{-1}), marginally fit (RSC=1.25-2.5 me L^{-1}) and unfit (RSC >2.5 me L^{-1}) and from sodium adsorption ratio (SAR) point of view, fit (SAR< 6 mmol $L^{-1})^{½}$, marginally fit (SAR=6-10 mmol $L^{-1})^{1/2}$ and unfit (SAR >10 mmol $L^{-1})^{1/2}$. The results indicated that water samples in the percentage of 72.0, 62.7 and 54.4 in tehsils of Shuja Abad, Jalalpur Pir Wala and Multan, respectively were found unfit for irrigation purpose. Maximal percentage of 32.4 and minimal 11.6 of water samples were classified as fit samples in tehsil Multan and Shuja Abad, respectively. Thereby, 58.86 % water samples were considered unfit for irrigation purpose. Overall 64.4% and 5.1% water samples had EC and RSC above the permissible limits. The deleterious effects of salts could be mitigated by mixing of brackish water with surface canal water in various proportions and/or intermittent flushing of soil profile with good quality irrigation water. This practice may be carried out periodically to avoid economic yield losses.

Keywords: Brackish water, district Multan, EC, RSC, SAR, underground water.

INTRODUCTION

Water resource is a basic input for successful cultivation of crops under an arid and semi-arid environment. The agricultural production areas are consistently subjected to continuously or intermittent non-availability of water during the crop

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growth. Pakistan is also facing the similar situation, as its most part lies in an arid environment (Khalid *et al*., 2003). During the most part of the season, sufficient quantity of water is not available for exploiting the potential yield of crops. Thereby, underground water resources are utilized to meet the wholly or partial demand of crop. Chaudhry (1996) reported that in most of the cases, the quality of underground water resources for irrigation purpose is un-fit for crop production, and produces negative impacts on productivity of crops. Hussain *et al*. (1994) enumerated that 75% of the tubewells installed in the Punjab province are extracting water, which is unfit for direct application of irrigation water and needed appropriate treatments to reduce the deleterious effects of salts for sustaining crop production. The salinization of soils is a major threat to agriculture, which is being further compounded by irrigating the soils with hazardous groundwater. There are reports that underground waters being pumped in district Kasur varied greatly in its chemical composition and 70% water samples were found unfit for irrigation purpose (Shakir *et al*., 2002). Analogous to this, the proportion of quality of irrigation water varied in terms of 20% unfit, 9% marginally fit and 71% fit for irrigation use in district Rawalpindi (Khalid *et al*., 2003). Various researchers reported that out of the total, 48% and 76.6% installed tubewells in districts Gujrat and Lahore, respectively, were pumping water unfit for irrigation use (Pervaiz *et al*., 2003; Ali *et al.,* 2009). Similarly, Mehboob *et al*. (2011) reported that underground water being pumped in Chunian, Pattoki, Kot Radha Kishan and Kasur areas was 60%, 90%, 90% and 86%, respectively, classified as unfit for irrigation. This study further showed that 97% water samples were unfit with regard to EC (1250 µS cm^{-1}), 63% (SAR > 10 mmol L^{-1}) and 97% (RSC> 2.5 me L^{-1}) among the lot. The irrigation water containing excessive amounts of chloride, sulphate, bicarbonate, sodium, calcium, magnesium, potassium and nitrates results in not only reduction of the fertility of soils, but also lowering the economic yield (Ashraf., 1994; Rhodes *et al*., 2002). The reduction in yield is in proportionate to alone and/or combined action of these ions on stage of plant growth and crop varieties (Zhu, 2002). Ashraf (1994) reported that yield may be reduced by two-thirds of yield potential. The reason being that excess salts reduce the ability of plant to absorb water and causes slowed vegetative and root growth. Various researchers (Yang *et al*., 1990; Francois and Maas, 1994; Burman *et al*., 2003) reported that yield of most of crop plants may be reduced by 50-70 %, because of higher amounts of toxic salts. Apart from surveys conducted in other parts of the province, a little documented data are available about the quality of water being pumped in district Multan. The farmers resort to apply tubewell water during the short supply of water from surface canal system. Therefore, a survey was conducted to determine the quality of water being pumped by the tubewells in district Multan.

MATERIALS AND METHODS

This study was conducted to collect underground water samples for analyzing their quality for irrigation use. During the survey, 2686 water samples were collected from underground resources from three tehsils during 2001 to 2010. Of the total 2686, 1877, 549 and 260 samples were collected from Multan, Shuja Abad and Jabalpur Pirwala tehsils, respectively. The water samples were gathered from the running tubewells in plastic bottles. On an average, the depth of tubewells was about 120 feet. The map of district Multan showing GPS (Global Positioning System) of the locations of the tubwells is shown in Map 1. The chemical constituents of the waters such as electrical conductivity (EC), Ca^{2+}, Mg^{2+}, Na^{+}, CO_3^{2-}, HCO_3^{-} and Cl^{-} were analyzed as described by Page *et al*. (1982). The values of sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) were calculated according to the method proposed by US Salinity Laboratory Staff (1954).

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

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

Criteria for assessing the quality of water for irrigation purpose were followed those of Malik *et al*. (1984). The data was statistically analysed as proposed by Steel and Torrie (1980).

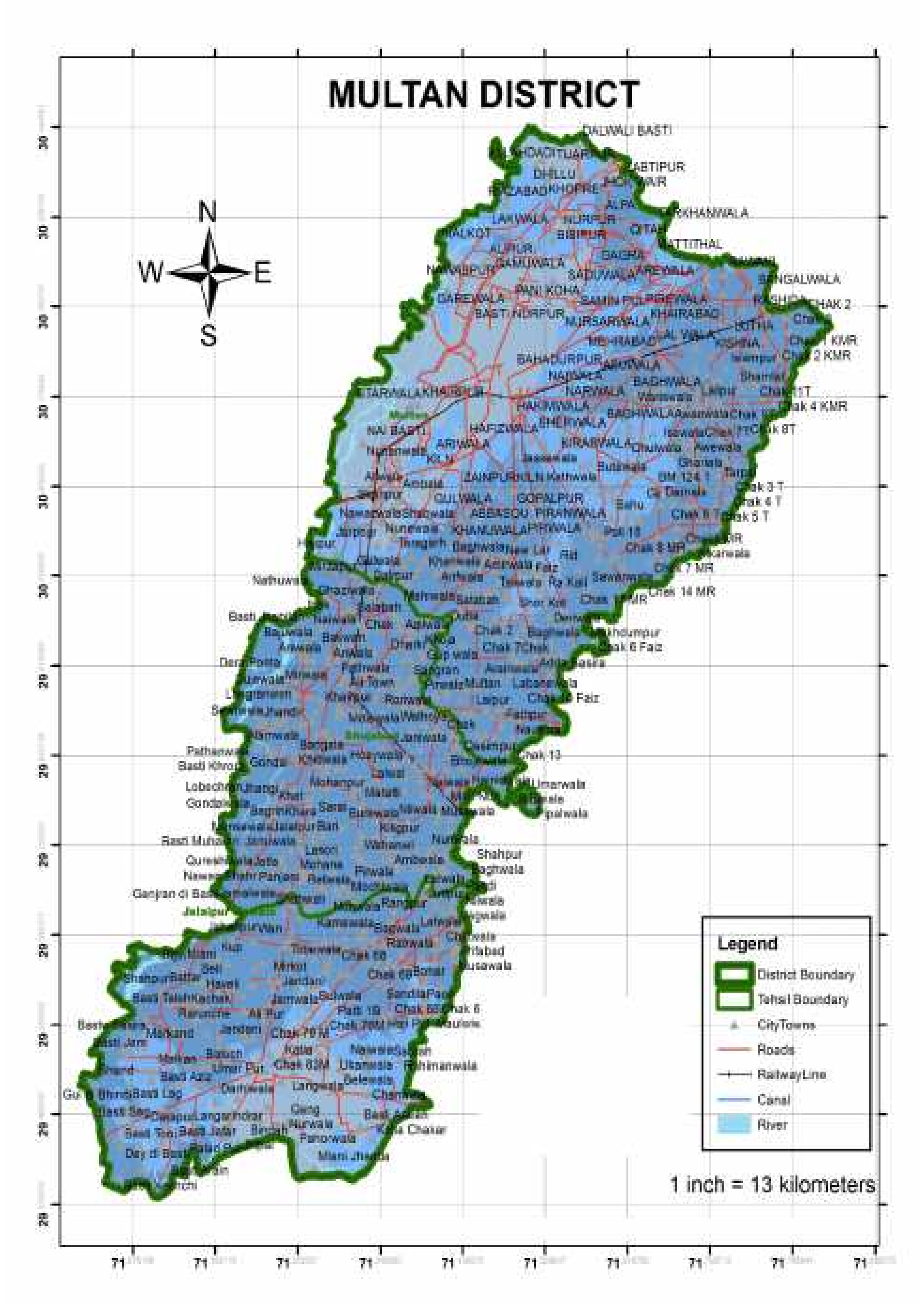
RESULTS

Electrical conductivity of underground water

Out of 2686 groundwater samples, 608 samples of Multan tehsil, 64 samples from Shuja Abad tehsil and 71 samples from Jalalpur Pirwala were considered fit for irrigation purpose. The mean values of fit samples were 32.4%, from Multan tehsil, 11.6 % from Shuja Abad tehsil and 27.3 % from Jalalpur Pirwala tehsil, respectively. Out of total, 13.1%, 16.4% and 10 % were found marginally fit for irrigation purpose collected from Multan, Shuja Abad, and Jalalpur Pirwala tehsils, respectively (Table 2, Figure 1). While 631 number of samples from Multan tehsil, 267 number of samples from Shuja Abad tehsil and 120 from Jalalpur Pirwala samples were extremely unfit for irrigation purpose on the basis of salt content data (Table 3).

Sodium adsorption ratio (SAR) of underground water

Out of the total unfit (1023) water samples in Multan tehsil, 133 were unfit because higher of levels of EC and SAR (Table 3). The values of SAR ranged from -0.30 to 94.13 $(mmol\ L^{-1})^{1/2}$ with a mean value of 4.72 $(mmol\ L^{-1})^{1/2}$ in Multan tehsil (Table 4). In case of Shuja Abad tehsil, out of 395 unfit water samples, 42 were unfit due to high SAR. The values of SAR ranged from 0.10 to 38 $(mmol\ L^{-1})^{1/2}$ with a mean value of 5.66 $(mmol\ L^{-1})^{1/2}$. While in tehsil Jalalpur Pirwala, out of 163 unfit water samples, 34 were unfit due to high SAR. The values of SAR ranged from 0.10 to 27.10 $(mmol\ L^{-1})^{1/2}$ with a mean value of 5.16 $(mmol\ L^{-1})^{1/2}$ (Table 4).



Map 1. Locations of tubewells identified with GPS.

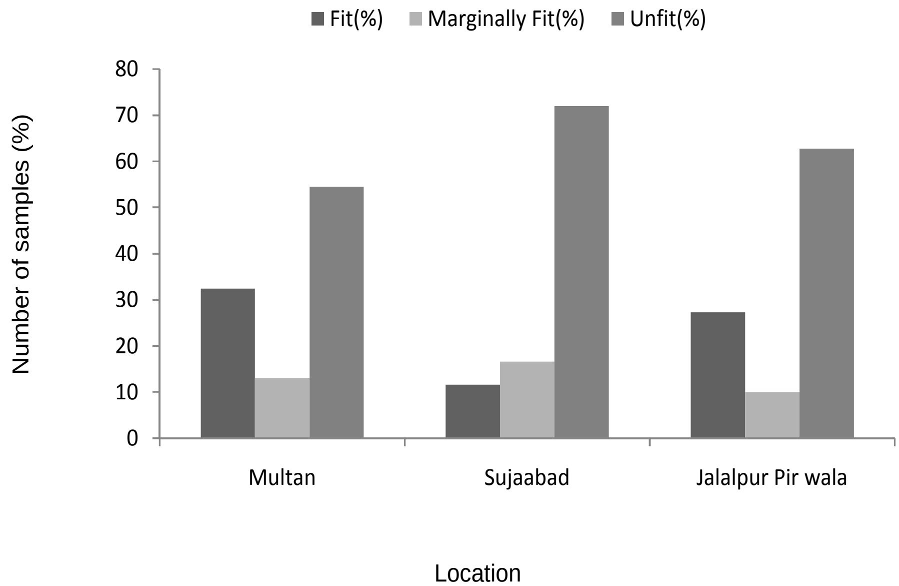


Figure 1. Underground water quality in Multan district.

Residual sodium carbonate (RSC) of underground water

Out of the total unfit (1023) water samples in Multan tehsil, 52 were solely unfit due to higher values of RSC (Table 3). The values of RSC ranged from 0 to 27.46 me L^{-1} and a mean value of 0.91 me L^{-1} in Multan tehsil (Table 4). In case of Shuja Abad tehsil , out of 395 unfit water samples 30 were unfit due to high RSC (>2.25 me L^{-1}).The values of RSC ranged from 0 to 9.50 me L^{-1} with a mean value of 0.82 me L^{-1}. While in tehsil, Jalalpur Pirwala the values of RSC ranged from 0 to 15.83 me L^{-1} with a mean value of 0.25 me L^{-1} (Table 4).

Table 1. Criteria for quality of irrigation water.

Status	EC (µS cm^{-1})	SAR ($mmolL^{-1})^{1/2}$	RSC (me L^{-1})
Fit	< 1000	6	<1.25
Marginally Fit	1001-1250	6-10	1.25-2.5
Unfit	> 1250	>10	>2.5

Source: Malik *et al*., (1984)

Table 2. Underground water quality of district Multan for the years 2001 to 2010.

Tehsil	Fit	Marginally Fit	Unfit	Total
Multan	608	246	1023	1877
Shujabad	64	90	395	549
Jalalpur Pirwala	71	26	163	260

Table 3. Classification of unfit underground water samples in respect to EC, SAR and RSC in Multan district for the years 2001 to 2010.

Tehsil	EC	RSC	EC+SAR	EC+RSC	EC+ SAR+ RCS	Total
Multan	631 (61.7)	52 (5.1)	133 (13.0)	121(11.8)	86 (8.4)	1023
Shujabad	267 (67.6)	30 (7.6)	42 (10.6)	42 (10.6)	14 (3.5)	395
Jabalpur Pirwala	120 (73.6)	-	34 (20.9)	6 (3.7)	3 (1.8)	163

Figures in parenthesis are percentage of total.

Table 4. Descriptive statistics for underground water quality characteristics of district Multan (2001-2010).

Parameters	Tehsil Multan	Tehsil Shujabad	Tehsil Jalalpur Pirwala
EC (µS cm^{-1})			
Minimum	5.60 (10.68 kg salt ha^{-1})*	290.0 (565.2 kg salt ha^{-1})	400 (779.5. kg salt ha^{-1})
Maximum	180009 (14201 kg salt ha^{-1})	159759 (33718 kg salt ha^{-1})	11618 (22640.5. kg salt ha^{-})
Average	1894.2 (3690.5 kg salt ha^{-1})	2661 (5185.4 kg salt ha^{-1})	3028(6251.5 kg salt ha^{-1})
Standard deviation	1769.6	2106.9	2434
Coefficient of Variation (%)	93.42	79.18	80.38
Sodium adsorption ratio [(mmolL^{-1})$^{1/2}$]			
Minimum	-0.30	0.10	0.10
Maximum	94.13	38.00	27.10
Average	4.72	5.66	5.16
Standard deviation	4.45	4.49	4.54
Coefficient of Variation (%)	94.13	79.28	87.95
Residual sodium Carbonate (me L^{-1})			
Minimum	0.00	0.00	0.00
Maximum	27.46	9.50	15.83
Average	0.91	0.82	0.25
Standard deviation	1.92	1.50	1.18
Coefficient of Variation (%)	209.67	182.38	478.47

*EC (dSm^{-1}) × 640 = mg L^{-1} and 1 acre foot irrigation water = 198 × 220 × 1 = 43560 cubic feet One cubic feet = 28.3 liters, 1 acre foot = 43560 × 28.3 = 1232748 liters Parts per million (ppm) = 1mg or10^{-6} kg L^{-1}. So, 1 acre foot irrigation = 10^{-6}× 1232748 = 1.23275 kg salts, OR I hectare foot irrigation =3.04488 kg salt ha^{-1}.

DISCUSSION

This field survey revealed that majority of water sampes taken from underground water resources of the area was not suitable because of higher electrical conductivity values, however, causing no sodicity problem insight. The reason being that soils of district Multan are medium textured, lower depths are well developed and containing high lime content. The presence of lime in the parent material, lower water table, and decreased infiltration rate from the surface flow of water might have resulted in increased electrical conductivity, and thus leaving water unfit for irrigation use (Rashid, 1996). There are estimates that presence of higher EC may result in the buildup of salts from 565.11 to 31,131.0 kg salts ha^{-1} (Bennett *et al*., 2007). The application of brackish water without prior appropriate treatment is the major cause of salinity. However, the impact of brackish water on the productivity and quality of crop plants could vary greatly under various climatic conditions and management practices (Singh *et al*., 1992). Pervaiz *et al*. (2003) suggested that irrigation water having EC up to 1025 µS cm^{-1} could be used safely on heavy textured soils by avoiding any significant reduction in most of crop plants. According to the reports of WWF (2007), the quality of water containing EC < 3000 µS cm^{-1}, SAR 10 (mmol $L^{-1})^{1/2}$ and RSC < 2.5 me L^{-1} could be used safely in coarse textured soils, whereas, the water having EC (2300 µS cm^{-1}), SAR (8 mmol $L^{-1})^{1/2}$ and RSC (2.3 me L^{-1}) may be considered suitable for medium textured soils. On the other hand, the water having EC 1500 µS cm^{-1}, SAR (8 mmol $L^{-11/2}$) and RSC (1.25 me L^{-1}) is fit for fine textured soils. In general, water containing EC less than 750 µS cm^{-1} may not cause any problem of salinization and is suitable for irrigation purpose. The findings of this study agree with results of many other researchers (Shakir *et al*., 2002; Khalid *et al*., 2003; Pervaiz *et al*., 2003; Ali *et al*., 2009) that quality of underground water was quite variable with regard to irrigation purpose. About two thirds of tubewell water in the Punjab province is unfit for irrigation use.

The application of brackish water directly causes buildup of salts to an unacceptable limit with concurrent heavy reduction in crop yields. This scenario could be alleviated by proper management of irrigation water before its usage. The agronomic measures including deep tillage practices, addition of soil amendments, use of salt-tolerant varieties, growing crops on ridges, alternatively proper mixing of brackish water with quality graded water and/or alternate watering of crops with brackish and quality water. The salt tolerant crops, for example wheat, rice, barley, sorghum and fruit trees for example guava, jujuba, dates, and blueberry could be irrigated with marginally unfit waters. The poor quality irrigation water may also be used for growing timbers fruit e.g. trees Eucalyptus, Acacia and Atriplex spp. for grazing purpose (Waheed *et al.*, 2010 ; Mehboob *et al*., 2011). The water containing higher SAR and RSC may be avoided for irrigation purpose. The reason being that underground water containing higher contents of sodium, carbonates and bicarbonates accelerate the process of salinization, and simultaneously deteriorating the soil hydraulic and permeability (Ghafoor *et al*., 2002). In certain cases, where the source of irrigation water is solely dependent upon the brackish water, then special water treatments and farm management practices sought to be done to mitigate the deleterious impacts of salts (Ashraf *et al*., 2005; Keshavarzi *et al*., 2010). The impact of various constituents and their composition is variable due to their inherent toxicity levels, viz, reduction in permeability and infiltration due to high SAR and RSC; reduction in biological and economic yield due to higher content of sodium and higher values of RSC cause increase in sodium content.

The negative effects of RSC and SAR containing irrigation water could be alleviated by addition of gypsum ($CaSO_4.2H_2O$), commercial sulphuric acid (H_2SO_4) and acid forming amendments either in soil or water (Ali *et al*., 2009; Mehboob *et al*., 2011). The application of organic material (pressmud, poultry manure, farmyard manure), deep ploughing and cultivation of salt-tolerant crop varieties are being employed and advocated to ameliorate the toxic effects of brackish water (Ashraf *et al*., 2005; Mehboob *et al*., 2011). Apart from this, adoption of biosaline agriculture, rearing of sheep and goat and aquaculture (fish farming), growing of trees (*Eucalyptus, Acacia*) for timber and fuel purpose, and *Atriplex* species for grazing purpose offer profitable strategies for subsistence farming and livelihood under stressful environment of brackish water in most of the regions. The deleterious effects of salts could be mitigated by mixing of brackish water with surface canal water in various proportions and/or intermittent flushing of soil profile with good irrigation water. These practices may be carried out periodically to avoid economic yield losses.

CONCLUSION

The field survey conducted in Multan district revealed that a greater proportionate number of tubewells extracted marginal to unfit water for irrigation purpose. The underground water is considered unfit due to higher values of electrical conductivity, and sodium adsorption ratio. The brackish water may be used in conjunction with adoption of certain strategies, (i) agronomic (deep ploughing, growing on raised beds, cultivating salt-tolerant crop), (ii) soil amendments (organic: farm yard manure, poultry manure, pressmud; inorganic: gypsum, sulphuric acid), (iii) biosaline agriculture (growing of *Eucalptus, Acaia, Atriplex*) and cyclic irrigation and/or prior mixing with canal water. The direct application of brackish water warrants for successful and profitable agriculture in Multan district.

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