Soil & Environ. 28(1): 17-23, 2009
www.se.org.pk

Irrigation quality of ground water of twenty villages in Lahore district

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Abstract

A study was conducted in twenty villages of Lahore district to assess the suitability of ground water for irrigation. Three water samples were collected from each of twenty villages and were analyzed for electrical conductivity (EC), sodium adsorption ratio (SAR), residual sodium carbonate (RSC) and chloride concentration. Out of total 60 water samples, 7 (11.7%) were fit, 7 (11.7%) were marginally fit, and remaining 46 (76.6%) were unfit for irrigation. Twenty eight samples (46.6%) had electrical conductivity higher than permissible limit (i.e. >1250 µS cm^{-1}), 19 samples (31.6%) were found with high SAR (i.e. >10 (m mol L^{-1})$^{0.5}$), 44 samples (73.3%) had high RSC (i.e. >2.5 me L^{-1}) and 10 samples (16.6%) were found unfit for irrigation due to high concentration of chloride (i.e. >3.9 me L^{-1}). It can be inferred from data that quality of available ground water in most of the villages is not suitable for sustainable crop production and soil health.

Key words: Ground water, EC, SAR, RSC, Lahore

Introduction

Pakistan is basically an agricultural country but most of its agriculturally productive area falls in the arid and semi-arid climate. The rainfall varies considerably with less than 10 mm per annum in some parts of the country to more than 500 mm in other parts (Bhutta *et al.,* 2002). Most of the rainfall is during the month of July to September (monsoon). So, potential production can not be achieved without ensured irrigation supplies.

Due to change in climate and thereby extended drought, surface-water resources of Pakistan were reduced by about 70 percent in 2003, compared with normal years (Kahlown *et al.*, 2003). 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 tubewells. Irrigation through tubewells has advantage over rainfall of being under control with respect to time and amount of application.

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). According to Hussain *et al.* (1991) two third of under ground water of Punjab is unfit for irrigation and requires prior amendment or scientific management.

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.

In a similar 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.

For successful crops production on sustainable basis without deteriorating soils, the quality of ground water is of main concern. The common quality characteristics considered are electrical conductivity (EC), sodium adsorption ratio (SAR) and residual sodium carbonate (RSC). Present study was carried out to assess the ground water quality in Lahore district for its irrigation suitability.

Materials and Methods

Twenty villages of District Lahore were selected for this study. Water samples from 3 tubewells of each village were collected in plastic bottles after 30 minutes of tubewell operation during the month of October, 2005. Tubewell selection was made at random and depth of bores ranged from 60 to 200 feet.

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Analytical work was carried out at Soil and Water Testing Laboratories for Research, Thokar Niaz Baig, Lahore. These samples were analyzed for anions (CO_3^{--}, HCO_3^-, Cl^-), cations (Na^+, Ca^{++} + Mg^{++}), pH and EC. Sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) were calculated by following equations:

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

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

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

Results and Discussion

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).

Irrigation water quality parameters of twenty villages of Lahore district are given in Table 1. 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 total 60 water samples collected, only 7 were fit, 7 were marginally fit and remaining 46 samples were unfit for irrigation (Table 5 and Figure 1). Most of the samples were unfit due to high EC + SAR + RSC followed by high RSC and EC + RSC (Table 5).

Electrical conductivity (EC)

Electrical conductivity of water samples ranged from 410 to 3370 µS cm^{-1} with mean of 1363.83 µS cm^{-1} and standard deviation of 677.43. Twenty one samples out of 60 have EC <1000 µS cm^{-1}, 11 samples have EC between 1001 to 1250 µS cm^{-1} whereas all other 28 samples have EC >1250 µS cm^{-1} (Table 2 and 4).

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).

Sodium adsorption ratio (SAR)

It represents the relative proportion of Na to Ca + Mg. The SAR of water samples ranged from 0.1 to 33.5 with mean of 8.69 and standard deviation of 7.44 (Table 2). Considering relative frequency distribution regarding SAR (Table 4), 28 samples (47%) were fit, 13 samples (22%) were marginally fit and remaining 19 samples (31%) were unfit.

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).

Salts added to soil (kg acre^{-1} foot of irrigation water)

Total soluble salts (ppm) of water multiplied with the factor 1.23275* gives kg of salts added to soil per acre foot of irrigation water applied. Crop growth reduction because of

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*EC (dS m^{-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 or 10^{-6} kg L^{-1}
So 1 acre foot irrigation = 10^{-6} × 1232748 = 1.23275 kg salts

dissolved substances in the soil is similar to drought stressed effects. An osmotic gradient on salt affected soils is formed and water uptake by plant roots is increasingly restricted as the concentration of soil salts increases. As salts build up in soil, more frequent irrigation is necessary to flush out salts from root zone. Crop species differ in their abilities to withstand salt stress.

Maximum salts i.e. 2658.8 kg with acre foot irrigation water are being added in soils of village Jodhu Dheer. Table 6 shows the amount of salts (Kg) added to soil per acre foot of irrigation.

Seven samples (12 %) out of 60 were fit, 9 samples (15 %) were marginally fit and remaining 44 samples (73 %) were unfit (Table 4).

The fitness of water of different sites depends upon the average condition of soil texture, quantity of irrigation water applied, soil drainage, infiltration rate etc along with other variables like climate and tolerance of crop to salts.

It was observed that most of the water samples were unfit due to high RSC (Table 5). Farmers can use high RSC water for growing crops after gypsum amendment. Gypsum requirement can be calculated by following formula:

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	-

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

Parameter	Range	Mean	Standard Deviation
EC (µS cm^{-1})	410-3370	1363.83	677.43
SAR	0.1-33.5	8.69	7.44
RSC (me L^{-1})	0-21.4	6.51	4.82
pH	8.4-9.1	8.73	0.24
Cl (me L^{-1})	0.1-9.8	2.28	2.32

Table 3. Conditions of water use and irrigation water quality parameters

Conditions of use	EC (µs cm^{-1})	SAR	RSC (me L^{-1})
Coarse Textured Soil	3000	10	2.50
MediumTextured Soil	2300	08	2.30
Fine Textured Soil	1500	08	1.25

Irrigation water quality guidelines for Pakistan, proposed by WWF (2007)

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 21.4 me L^{-1} with mean of 6.51 me L^{-1} and standard deviation of 4.82 (Table 2).

Gypsum requirement (kg) =

$$\text{RSC (me } L^{-1}) \times \text{discharge (cusec)} \times \text{working hours} \times 8.8$$

Water quality also depends upon texture of the soil. Irrigation water unfit for fine textured soils might not be so

Table 4. Relative frequency distribution of tubewell waters for different irrigation quality characteristics, Lahore

Parameter	Class interval	Relative freq. distribution		Status
		No. of Sample	(%)	
Electrical conductivity, EC (µS cm^{-1})	<1000	21	35	Fit
	1001-1250	11	18	Marginally Fit
	>1250	28	47	Unfit
Sodium Adsorption Ratio, SAR (m mol $L^{-1})^{1/2}$	<6	28	47	Fit
	6-10	13	22	Marginally Fit
	>10	19	31	Unfit
Residual Sodium Carbonate, RSC (me L^{-1})	<1.25	7	12	Fit
	1.25-2.50	9	15	Marginally Fit
	>2.50	44	73	Unfit
Chloride (me L^{-1})	0-3.9	50	83	Fit
	>3.9	10	17	Unfit

Table 5. Village wise suitability categorization of water samples for irrigation

Sr. No.	Village	Fit	M. Fit	Un-Fit	Unfit due to				
					EC	RSC	EC + RSC	SAR + RSC	EC+SAR+RSC
1.	Maleyan	-	-	3	-	-	3	-	-
2.	Tatlay	-	1	2	-	1	1	-	-
3.	Haier	-	1	2	-	1	1	-	-
4.	Thather	-	-	3	-	3	-	-	-
5.	Sodakey	-	-	3	-	1	-	-	2
6.	Saraiech	2	1	-	-	-	-	-	-
7.	Mahdeepur	-	-	3	-	2	1	-	-
8.	Jhanp	-	-	3	-	1	-	1	1
9.	Havely Habibullah	-	-	3	-	1	1	-	1
10.	Galvera	-	1	2	1	-	-	1	-
11.	Suwaasal	3	-	-	-	-	-	-	-
12.	Ludaykay Bhular	-	2	1	-	1	-	-	-
13.	Pandokee	-	-	3	1	1	-	-	1
14.	Watna	2	-	1	-	1	-	-	-
15.	Jodhu Dheer	-	1	2	-	-	1	-	1
16.	Dhonday	-	-	3	-	1	1	-	1
17.	Karyal	-	-	3	-	1	-	-	2
18.	Jeeyabagga	-	-	3	-	1	-	-	2
19.	Kung Sharif	-	-	3	-	-	-	-	3
20.	Jhedhu	-	-	3	-	-	-	-	3
Total =		**7**	**7**	**46**	**2**	**16**	**9**	**2**	**17**

for coarse textured soils (Table 3). Farmers can use marginal and unfit water for salt tolerant crops like wheat, sorghum etc as these crops have physiology for moderating the ill effects of salts.

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.

Table 6. Village wise range, mean and standard deviation of water samples

Village Name		EC µS cm^{-1}	SAR	RSC me L^{-1}	Salts Added Kg/acre
Maleyan	*Range*	1351-1884	3.9-9.8	4.0-10.6	1065.9-1486.4
	Mean	1672.33	7.8	8.27	-
	S.D.	282.92	3.38	3.70	-
Tatlay	*Range*	720-1400	2.0-5.2	2.4-5.1	568-1104.5
	Mean	976.67	3.4	3.83	-
	S.D.	369.37	1.64	1.36	-
Haier	*Range*	710-1280	1.8-7.2	2.5-7.0	560.2-1009.9
	Mean	1047.33	4.4	4.93	-
	S.D.	299.07	2.70	2.27	-
Thather	*Range*	758-1065	4.2-9.5	4-6.7	598-840.2
	Mean	861	6.3	5.03	-
	S.D.	176.67	2.82	1.46	-
Sodakey	*Range*	1166-1565	7.4-13	4.9-10.4	920-1234.7
	Mean	1430.67	10.6	8.53	-
	S.D.	229.22	2.88	3.15	-
Saraiech	*Range*	410-720	0.1-3.5	0-2.2	323.5-568
	Mean	533.33	1.97	1.13	-
	S.D.	164.42	1.72	1.10	-
Mahdeepur	*Range*	1040-1322	6.1-8.9	4.4-7.8	820.5-1043
	Mean	1174	7.43	5.97	-
	S.D.	141.52	1.40	1.72	-
Jhanp	*Range*	1170-1760	10-20	6.5-10.9	923-1388.6
	Mean	1380	13.93	8.1	-
	S.D.	329.70	5.33	2.43	-
Havely Habibullah	*Range*	1003-1620	2.2-11.3	3.3-8.2	791.3-1278.1
	Mean	1321	5.83	5.27	-
	S.D.	308.94	4.82	2.59	-
Galvera	*Range*	710-1800	1.7-12	2.4-9.6	560.2-1420.1
	Mean	1253.33	5.63	4.83	-
	S.D.	545.01	5.56	4.13	-
Suwa Aasal	*Range*	840-990	1.2-2.2	0.8-1.2	662.7-781
	Mean	938	1.8	1	-
	S.D.	84.92	0.53	0.2	-
Ludaykay Bhular	*Range*	840-1100	1.8-4.3	1.9-4.1	662.7-867.8
	Mean	956.67	2.7	2.8	-
	S.D.	132.03	1.39	1.15	-
Pandokee	*Range*	1215-1740	4.9-11.1	1.4-10.4	958.6-1372.8
	Mean	1455.33	8.07	5.47	-
	S.D.	265.29	3.10	4.56	-
Watna	*Range*	552-884	0.3-4.8	0-3.7	435.5-697.4
	Mean	665.33	1.97	1.47	-
	S.D.	189.41	2.47	1.96	-
Jodhu Dheer	*Range*	600-3370	2.5-33.5	2.1-21.4	473.4-2658.8
	Mean	1776.67	13.87	9.63	-
	S.D.	1431.23	17.07	10.32	-
Dhonday	*Range*	980-1837	2-15.3	2.9-12	773.2-1449.3
	Mean	1475.67	8.33	7.47	-
	S.D.	444.01	6.67	4.55	-
Karyal	*Range*	770-1930	6.1-29	4.2-14.8	607.5-1522.6
	Mean	1448	18.23	10.93	-
	S.D.	604.33	11.51	5.85	-

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Jeeyabagga	*Range*	684-2490	6.1-19.9	3.5-15.3	539.6-1964.5
	Mean	1644.67	12.6	8.9	-
	S.D.	908.51	6.93	5.96	-
Kung Sharif	*Range*	2480-3180	18.9-21.3	10.7-16.3	1956.6-2508.9
	Mean	2720	20.4	13.37	-
	S.D.	398.50	1.31	2.81	-
Jhedhu	*Range*	2100-3200	16.9-20.7	11.6-15.4	1656.8-2524.6
	Mean	2546.67	18.53	13.33	-
	S.D.	578.39	1.95	1.92	-

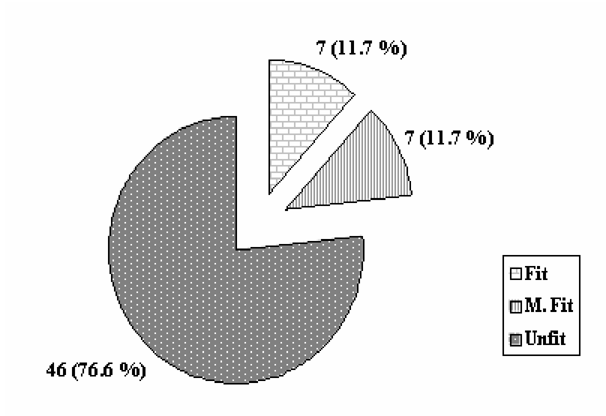

Figure 1. Irrigation water quality of Lahore District

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).

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