SOURCES AND QUALITY OF IRRIGATION WATER IN DISTRICT ATTOCK

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ABSTRACT

Rainfall is a major source of irrigation water for crops in district Attock, Pakistan where average amount of 694 mm is received per annum (tehsil Attock 714 mm, Fateh Jang 825, Pindi Gheb 360, Jand 544 and Hassan Abdal 1029 mm). Determination of water quality through analysis is pre-requisite for its better utilization by crops as it is essential for the maintenance of turgidity, absorption of nutrients and metabolic processes of plants. A survey was conducted at Soil and Water Testing Laboratory, Attock from the year 2004-05 to 2008-09. A total of 192 water samples were collected from all tehsils of Attock district. The analysed data showed that 88 samples (46 %) were fit, 27 samples (14 %) were marginally fit while 77 samples (40 %) were not fit for irrigation to crops. As regards minimum and maximum range, electrical conductivity varied from 352-10590 µS/cm, total dissolved salts from 246.4 to 7413 mg/L, calcium plus magnesium from zero to 90 me/L, sodium from 0.04 to 81.60 me/L, carbonates ranged from zero to 0.50 me/L, bicarbonates from 2.0 to 20.0 me/L, chlorides from 0.5 to 90.0 me/L, sodium adsorption ratio from zero to 60.53 and residual sodium carbonate ranged from zero to 9.10 me/L. Suggestions for wise and judicious use of good quality water for raising high value cash crops, vegetables and fruit plants were given to farmers. As regards marginally fit and unfit irrigation water, suitable remedial measures were suggested considering salinity or sodicity of irrigation water.

KEYWORDS: Irrigation water; water reservoirs; chemicophysical properties; bicarbonates; Pakistan.

INTRODUCTION

Water is important for survival and existence of life as the Creator of universe said in the Holy Quran, “And We made every living thing of water *(Surah: Al-anbiya; ayah: 30)* and We have sent down from the rainy clouds abundant water, thereby to produce grain and plant *(Surah: Al-naba; ayah: 14-15)*”. Water is being used intensively for agricultural purposes (90%), domestic

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(6%) and industrial (3%) needs (21). Surface water supplies do not meet the crop water requirements as net deliveries of surface water are 1.80 acre feet per cropped area, not commensurate with optimum water requirements estimated at 4-5 acre feet (41). Efficient use of water for crop production is vital for agriculture. Water availability influences nutrient availability through its effect on mass flow and diffusion. Increasing water availability facilitates nutrient diffusion while soil texture interacts with water contents (8).

The area in district Attock has gentle to steep topography with deep water table (15 m) in north east (tehsil Hazro) to very deep (120 m) in south west (tehsils Jand and Pindi Gheb) as known from the personal survey of the area. The rainfed area is underfed from the view point of application of inputs as compared to output obtained. Soils of district Attock are not only thirsty but hungry also owing to poor organic matter and other essential nutrients for plants as these soils are calcareous, high in reaction (pH) and mostly light textured. Moisture distribution in the area is not uniform. Almost 60-70 percent rainfall occurs in months of mid June to mid September (36, 40, 42). Thus there is need to conserve soil moisture for boosting crop production. In the recent past, some small dams have been constructed for irrigation, drinking water and fish farming and this development has influenced ground water locally (39). Salient features of small dams in district Attock are depicted in Annexure-I.

Shafiq *et al*. (36) has classified Attock district into sub-humid (Hazro, Bahtar) and semi arid (Attock, Pindi Gheb) and suggested measures to check soil and water erosion. According to Shafiq *et al*. (38), the undulating field conditions aggravate the problems like soil erosion, moisture wastage, over wetness and drought through uneven water distribution in the soil. To overcome the drought stress in rainfed areas, Zia *et al*. (47) suggested moisture conservation techniques by tillage practices and mulch application. Water storage provides additional water for the crops and improves water use efficiency. The runoff may also be collected and stored in reservoirs and used for supplemental irrigation (11). Response to water harvesting is always site specific. Selection of techniques based on different factors such as topography, soil type, land use, pattern and intensity of rainfall, crops to be grown and the climatic conditions (26). Water harvesting technique if appropriately applied could help the establishment of plants without artificial irrigation (20). Water productivity and fertilizer use efficiency are directly linked with the rainfall and moisture in the root zone during crop growth. Under limited moisture supply condition, low level of balanced fertilizer (NP@50-25 kg/ha) produced 71 percent more grain yield than control and most economical (benefit cost ratio 7.01) and profitable wheat production under rainfed condition (30) and similar results have also been obtained in another study (4).

Ground water in arid and semi arid regions is generally high in salinity varying from <1 dS/m to >12-15 dS/m electrical conductivity (EC). Pervaiz (27) analysed 52 water samples of UC Gakhar Kalan in district Gujrat, Pakistan from tubewells and found 7 percent samples fit, 33 percent marginally fit and 60 percent unfit for irrigation The unfit samples were due to high EC followed by residual sodium carbonate (RSC) and EC+RSC but on the other hand, 40 percent samples of water analysed on whole district basis were fit, 23 percent marginally fit and rest 37 percent unfit for irrigation (28). Similarly, Ali *et al*. (3) analysed 60 ground water samples of Lahore district out of which 11.7, 11.7 and 62.6 percent samples were fit, marginally fit and unfit, respectively inferring that quality of most of the samples is not suitable for sustainable crop production and soil health. Brackish water can be effectively used for irrigation of crops if proper management practices and amendments are followed (5). Haq *et al*. (15) suggested the application of both manures and gypsum for mitigating the ill effects of brackish water and improving soil conditions to increase wheat yield. Rashid *et al*. (31) investigated the effect of brackish water on crop yields and soil properties treated with amendments like gypsum and farm yard manure. Modern irrigation practices have contributed to salt accumulation as one cusec is generally applied to 333 acres in Pakistan as compared to 100 acres in western part of the United States and other countries under similar climatic conditions. Hence irrigation water cannot wash down salts much beneath the root zone and consequently these accumulate in the upper surface of the soil (25). Jakhar *et al*. (17) reviewed the water quality research in Pakistan and described the effect of poor quality irrigation water on crop yield and soil properties.

The objective of this study was to assess the quality of irrigation water in district Attock and suggest remedial measures for its improvement for higher crop yields in district Attock.

MATERIALS AND METHODS

This study was conducted at Soil and Water Testing Laboratory, Attock, Pakistan during 2004-05 to 2008-09. A total of 192 water samples were collected from all tehsils of district Attock (101 from Attock, 16 from Fateh Jang, 12 from Pindi Gheb, 52 from Jand and 11 from Hassan Abdal) for irrigation purpose. Regarding sources of irrigation, 113 samples were collected from bores (turbine operated), 46 from open wells, 15 from tubewells, 11 from hand pumps, 4 from nullahs and 3 from dams. To determine the water quality status for irrigation, samples were collected from all tehsils of district Attock in clean plastic or glass bottles of one litre capacity fitted with screw cap. Before taking the sample, each bottle was labelled with the name of farmer and address, date of sampling, depth of ground water, crops and soil being irrigated and location with water-proof ink. For drawing the maximum benefit and validity, the sample taken was representative of the water in bulk quantity. The well or tubewell was run for half an hour prior to sampling and bottle was rinsed several times with water to be collected and then filled to the top and tightly capped. In case of pond, mini dam or stream, water was filled from inner side of the source. Samples were brought to the laboratory for chemical analysis. i.e. electrical conductivity (EC), cations; calcium + magnesium (Ca +Mg) and sodium (Na) by difference method i.e. [(TDS) - (Ca + Mg); anions (carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) and chloride (Cl^-)] according to the procedures given by Malik *et al*. (24). The calculations regarding total dissolved salts (TDS) and sodium adsorption ratio (SAR), were worked out as under according to Richards (34),

$$\text{TDS in g/m}^3 = \text{EC } (\mu\text{S/cm}) \times 0.64$$
$$\text{SAR in m mol/L} = \text{Na}/[\text{Ca} + \text{Mg}]^{0.5}$$
$$\text{RSC in me/L} = (CO_3 + HCO_3) - (\text{Ca} + \text{Mg})$$

The TDS in g/m^3 (ppm or mg/L) multiplied with the factor 1.23275 gives kg of salts added per acre foot irrigation. The factor is derived as under:-

$$\text{EC } (\mu\text{S/cm}) \times 0.64 = \text{mg/L}$$

1 acre foot irrigation water = 198x220x1 = 43560 feet^3 x 28.3 L = 1232748 L,
1 mg/L =10^{-6} kg of salts per litre of irrigation water, kg of salts per acre feet of irrigation water = 1232748 x 10^{-6} = 1.23275

The criterion of classification (EC, SAR and RSC) for fitness of irrigation water towards its suitability to crops is given in Table 1. The suitability of water for irrigation is actually ascertained considering EC of water, sensitivity of the crops to salinity, soil texture and permeability of the soil to water. On coarse textured soils with high permeability to water, it is possible to use water of higher salinity without adverse effects on crops yields but on soils with high clay percentage and low permeability, water of lower salinity is suitable. Otherwise salts added by irrigation water will accumulate in the soil and yield of salt sensitive crops will be adversely affected (44). ECe of soil extract is generally 2-3 times higher than ECe of irrigation water (34). Similarly high SAR and RSC waters will require special considerations before applying to soils and crops.

Table 1. Fitness criteria of irrigation water.

Parameter	Fit	Marginally fit	Unfit
EC (µS/cm)	0-1000	1000-1250	> 1250
SAR (m mol/L)$^{0.5}$	0-6	6-10	> 10
RSC (me/L)	0-1.25	1.25-2.50	> 2.50

Source: Malik *et al.* (24).

To ameliorate the ill effects of brackish water on the soil properties and crops, calcium and gypsum requirement of irrigation water can be calculated by the equation developed by Eaton (10) which considers two factors,

- Amount of cations and anions present in brackish water
- Amount of water to be used for crop production based on the consumptive use of the crops in rotation

Eaton's equation

A. Required Ca (me/L) = Sum of a, b and c as shown below:-

(a) Ca+Mg needed if any, so that the Na present will not exceed 70%
= Na x 0.43 – (Ca + Mg), retain + or- sign,

(b) Compensate for Ca+Mg that will probably be precipitated
= 0.7 x (CO_3 +HCO_3)

(c) Compensate for Ca+Mg in excess of Na that is removed from the land by average crops
= add 0.5 me/L

B. Gypsum equivalent of required Ca
= 234 x (a+b+c) pounds of gypsum if any, per acre foot of water (convert gypsum in tons per acre).

RESULTS AND DISCUSSION

Attock district falls in Potohar plateau where major source of water for irrigation to crops is rainfall. Rainfall intensity is erratic and variable, especially in rabi season determining farmers cropping pattern. Mean annual rainfall (2004-08) of different tehsils of district Attock is given in Table 2 which shows that maximum rainfall (1029 mm/year) is received in tehsil Hassan Abdal followed by tehsil Fateh Jang (825 mm), Attock (711 mm),

Table 2. Rainfall (mm) in district Attock (2004-08).

Year	Hassan Abdal	Fateh Jang	Attock	Jand	Pindi Gheb	Mean
2004	1087	762	658	465	339	662
2005	1196	857	956	641	472	824
2006	1084	745	531	409	344	623
2007	666	837	801	766	371	688
2008	1114	925	609	439	275	672
Mean	1029	825	711	544	360	694

Jand (544 mm) and minimum (360 mm) in tehsil Pindi Gheb. The year 2005 was the wettest year in all tehsils except tehsil Jand (where the year 2007 was the wettest) and tehsil Fateh Jang (where year 2008 was the wettest year) (Annexure II). Farrukh *et al.* (12) classified the northern Punjab into three rainfall zones i.e. low rainfall (250-500 mm), medium (500-750 mm) and high rainfall zone (>750mm). Rainfall pattern of Attock district (1989-93) was described by Rehman (32) in which average annual rainfall received in tehsil Attock was 701 mm, Fateh Jang 549 and Pindi Gheb 412 mm. Area of tehsil Fateh Jang falls between 750-1000 mm isohydel lines with the average (1983-94) annual rainfall of 862 mm (35). Shafiq *et al*. (37) devised a runoff farming technique for collecting precipitation and storing in the soil profile of cropped area. In Fateh Jang during 1986-1996, the lowest rainfall observed was 582 mm and the highest as 1103 mm with mean annual rainfall of 884 mm of which 50-66 percent was received during the monsoon season (July-September). In arid and semi arid regions like Pakistan, water for dry land crop production is supplied by precipitation that is limited and erratic. Sufficient precipitation is required during a growing season for a crop to explore its potential (46). Therefore, for more reliable crop production under such conditions, sufficient precipitation must be stored as soil water and efficiently used for crop production (43).

Different water sources for irrigation (surface and underground) are depicted in Table 3 having total command area of 3000 hectares. There are 14 perennial streams and nullahs (Haro, Soan, Sill, Naindna, Dotal, Raisi, Ghambir, Namal, Soka, Gandakas, Saghar, Ghanir, Jhablat and Kala Pani), 15 small dams (Annexure I), 300 mini dams, 200 ponds and 500 lift irrigation schemes from nullahs on the surface water. Besides this, river Indus and river Soan also pass along the boundaries of district Attock from where the nearby farmers use water for irrigation. As regards underground water sources, 1500 turbines are fitted on tubewells besides 1000 open wells operated by bullocks for irrigation. Water sources (surface and underground) and their quality alongwith impacts on soil and crop production have also been discussed by Chaudhry *et al*. (6).

Table 3. Water sources in district Attock.

Source	Number
Surface water	
Perennials streams, nullahs	12
Small dams	15
Mini dams	300
Ponds	200
Lift irrigation through perennial streams, nullahs	500
Underground water	
Tubewells, turbines	1500
Open wells	1000
Total command area (ha)	30000

The data on sources of water samples (Table 4) show that 59 percent samples were collected from lift schemes (bores) and 24 percent from open wells. Similarly, 53 percent samples were collected from tehsil Attock and 27 percent samples from tehsil Jand. The composition of different water sources varies with the season, rate of flow, silt and mud due to soil erosion and depth of sub-surface water.

Table 4. Sources of collected water samples.

Source	Attock	Jand	Fateh Jang	Pindi Gheb	Hassan Abdal	Total	Percentage
Lift schemes	60	32	5	9	7	113	59
Open wells	29	9	6	1	1	46	24
Tubewells	9	3	2	0	1	15	8
Hand pumps	1	7	0	1	2	11	6
Nullahs	0	1	2	1	0	4	2
Dams	2	0	1	0	0	3	1
Total	101	52	16	12	11	192	
Percentage	53	27	8	6	6		100

Chronologically, maximum number of water samples (62) were collected during the year 2005-06 followed by the year 2004-05 (56) and minimum samples (35 and 39) were collected in the years 2006-07 (35) and 2007-2008 (39) (Table 5).

Table 5. Year-wise water samples collected.

Year	Attock	Jand	Fateh Jang	Pindi Gheb	Hassan Abdal	Total
2004-05	27	17	6	4	2	56
2005-06	29	26	1	3	3	62
2006-07	18	5	7	1	4	35

2007-08	27	4	2	4	2	39
Total	101	52	16	12	11	192
Percentage	53	27	8	6	6	100

The quality of water samples analysed tehsil-wise (Table 6) and year-wise (Table 7) shows that 46 percent samples were fit, 14 percent marginally fit and 40 percent samples were not fit for irrigation in different tehsils.

Table 6. Quality of water samples tehsil-wise.

Tehsil	Fit	Marginally fit	Not fit	Total
Attock	52	14	35	101
Fateh Jang	3	0	13	16
Pindi Gheb	0	0	12	12
Jand	25	11	16	52
Hassan Abdal	8	2	1	11
Total	88	27	77	192
Percentage	46	14	40	100

Table 7. Quality of water samples year-wise

Year	Fit	Marginally fit	Not fit	Total
2004-05	17	11	28	56
2005-06	40	8	14	62
2006-07	18	5	12	35
2007-08	13	3	23	39
Total	88	27	77	192
Percentage	46	14	40	100

The quality of irrigation water of tubewells, open wells and ponds is also described by Rehman *et al*. (33). Ahmad *et al*. (1) analysed 3602 tubewell water samples for quality of irrigation and found 15 percent samples fit, 31 percent marginally fit and 54 percent unfit for irrigation. According to estimate, 25, 25 and 50 percent discharge of tubewells in the Punjab is useable, marginal and unfit, respectively for irrigation (23). Poor quality water can be used for crop production on a variety of soils provided proper agronomic practices coupled with chemical techniques like use of gypsum, farm yard manure and salt tolerant crops (14, 29) are followed.

The parameters of unfitness (Table 8) show that 76 percent samples were unfit due to EC, 8 percent due to EC+SAR and 5 percent samples due to RSC, EC+RSC and EC+SAR+RSC each. These results are in line with Ahmad *et al*. (1) and Pervaiz (27).

About 70-75 percent of the pumped groundwater in the Punjab province is unfit for irrigation owing to high EC, SAR and/or RSC which adversely affects the crop yields (13). Khan (19) while studying the suitability of water for irrigation purpose concluded that soil texture, type of crop, interval of irrigation, use of extra water for leaching, change of cultural practices, pre-plant irrigation, placement of seed and deep tillage should be taken into consideration.

Table 8. Unfitness of water due to different parameters.

Year	EC	EC+ SAR	RSC	EC+RSC	EC+SAR+ RSC	SAR+RSC	Total
2004-05	20	1	3	2	1	1	28
2005-06	9	1	0	2	2	0	14
2006-07	10	2	0	0	0	0	12
2007-08	19	2	1	0	1	0	23
Total	58	6	4	4	4	1	77
Percentage	76	8	5	5	5	1	100

Maximum EC (10590 µS/cm) and minimum EC (352 µS/cm) were found in tehsil Jand (Table 9). Likewise, maximum (7413 mg/L) and minimum (246.4 mg/L) TDS were also found in tehsil Jand. As regards Ca+Mg, maximum value (90.0 me/L) was present in tehsil Jand and minimum (nil) in tehsil Attock and Hassan Abdal (Table 9). Sodium (Na) was the highest (81.60 me/L) in tehsil Fateh Jang and the lowest (0.04 me/L) in tehsil Hassan Abdal. Carbonates (CO_3) were found only in tehsil Fateh Jang and absent in all other tehsils. The data further show that Cl^{-1} was maximum (90 me/L) and minimum (0.50 me/L) in tehsils Jand and Fateh Jang, respectively. SAR was higher (60.53) in tehsil Pindi Gheb and zero in tehsil Attock while RSC was maximum (9.10 me/L) in tehsil Pindi Gheb and found nil in all other tehsils except tehsil Pindi Gheb. Year-wise ranges of different parameters are also given in Table 10.

The data on river water quality show that Ca+Mg and HCO_3 ions are dominant constituents in water of the river Indus as its catchment area is underlain by rock composed of lime stone, sand stone, shale (sedimentary rocks) and slate, gneiss, schist, granodiorite and synite (igneous and metamorphic rocks) which solublise and minerals flow as a result of relatively high rainfall (18). Causes of improvement or deterioration of ground water quality over a span of 25 years in 2000 of SCARP-I tubewells were investigated by Lone and Beg (22) which were mainly due to CO_3 and HCO_3 ions and not due to Ca + Mg ions having no role in water quality deterioration. Reaction (pH) of water or solution also reflects its ionic composition as pH increases above 8.2, there is progressive increase in CO_3 and HCO_3 primarily associated with Na. As pH decreases below 8.2, there is increase in Cl and SO_4 associated with basic cations such as Ca, Mg, K and Na. At pH below 7.0, basic cations and PO_4 decrease but the concentration of H, Al and micronutrients such as Fe, Mn, Zn and Cu increase. The presence of soluble salts in higher concentration tends to depress the pH. If irrigation water is strongly alkaline, its use may result in more severe problem of alkalinity (16).

Table 9. Ranges of different parameters tehsil-wise

Tehsil	Year	EC (µS/cm)		T.D.S (mg/L)		Ca^{2+}+ Mg^{2+} (me/L)	
		Max.	Min.	Max.	Min.	Max.	Min.
Attock	2004-05	6560	425	4592	298	42.0	Nil
	2005-06	4430	427	3101	299	42.0	3.0
	2006-07	4130	365	2891	256	20.0	3.4
	2007-08	3990	399	2793	279	30.0	2.0
Fateh Jang	2004-05	4100	1087	2087	761	40.0	3.5
	2005-06	1748	1748	1224	124	8.5	8.5
	2006-07	9160	600	6412	420	50.0	5.4
	2007-08	3800	1847	2660	1293	30	9.5
Pindi Gheb	2004-05	6010	1579	4207	1105	40.0	4.5
	2005-06	5340	3052	3728	2136	30.0	5.0
	2006-07	3045	3045	2132	2132	7.0	7.0
	2007-08	6100	2764	4270	1935	40	0.40
Jand	2004-05	2475	464	1733	325	23.5	1.0
	2005-06	10590	352	7413	246.4	90.0	2.6
	2006-07	1182	352	827	246.4	6.5	3.3
	2007-08	5300	616	3710	431.2	50.0	1.0
Hassan Abdal	2004-05	827	544	579	380	7.0	5.4
	2005-06	1137	600	796	420	10.0	5.8
	2006-07	1137	689	796	482	10.0	6.0
	2007-08	1978	786	1384.6	550.2	16.0	7.0
		10590	352	7413	246.4	90.0	Nil
		Na+ (me/L)		CO_3 (me/L)		HCO_3 (me/L)	
		Max.	Min.	Max.	Min.	Max.	Min.
Attock	2004-05	25.6	0.17	Nil	Nil	15	2.0
	2005-06	7.8	0.08	Nil	Nil	9.0	3.0
	2006-07	21.30	0.17	Nil	Nil	8.5	2.8
	2007-08	22.90	0.49	Nil	Nil	14.50	3.2
Fateh Jang	2004-05	19.97	0.62	0.50	Nil	10.0	4.0
	2005-06	8.98	8.98	Nil	Nil	13.7	13.7
	2006-07	81.60	0.37	Nil	Nil	8.0	3.0
	2007-08	8.97	8.0	Nil	Nil	11.5	9.2
Pindi Ghab	2004-05	33.42	2.59	Nil	Nil	20	7.5
	2005-06	48.4	8.32	Nil	Nil	10.20	9.0
	2006-07	23.45	23.45	Nil	Nil	8.50	8.50
	2007-08	49.0	2.59	Nil	Nil	11	7.50
Jand	2004-05	14.92	0.47	Nil	Nil	8.0	2.0
	2005-06	41.0	0.19	Nil	Nil	10.5	2.0
	2006-07	8.02	0.22	Nil	Nil	5.60	2.80
	2007-08	11.87	0.85	Nil	Nil	7.0	3.80
Hasan Abdal	2004-05	1.27	0.04	Nil	Nil	5.0	3.5
	2005-06	1.37	0.20	Nil	Nil	7.5	4.8

	2006-07	1.37	0.89	Nil	Nil	7.50	5.0
	2007-08	3.78	0.86	Nil	Nil	8.0	4.0
		81.60	0.04	0.50	Nil	20.0	2.0
							Contd…..
		Cl (me/L)		SAR		RSC (me/L)	
		Max.	Min.	Max.	Min.	Max.	Min.
Attock	2004-05	54.0	1.0	5.6	Nil	4.8	Nil
	2005-06	32.5	1.0	3.3	0.05	1.20	Nil
	2006-07	30.0	0.50	6.74	0.09	Nil	Nil
	2007-08	25.0	0.80	8.25	0.30	1.20	Nil
Fateh Jang	2004-05	35	2.5	15.12	0.20	4.0	Nil
	2005-06	0.82	0.82	4.32	4.32	5.2	5.2
	2006-07	75.0	0.50	36.42	0.20	Nil	Nil
	2007-08	22.0	6.0	4.11	2.06	Nil	Nil
Pindi Gheb	2004-05	35.0	7.0	22	0.58	5.2	Nil
	2005-06	42.0	21.5	32.26	2.5	4.4	Nil
	2006-07	20.50	20.50	12.50	12.50	1.50	1.50
	2007-08	40.0	14.0	60.53	0.58	9.10	Nil
Jand	2004-05	15.0	1.5	10.55	0.29	5.5	Nil
	2005-06	90.0	0.60	15.05	0.12	7.7	Nil
	2006-07	6.0	0.60	5.81	0.17	0.80	Nil
	2007-08	42.0	1.40	7.37	0.40	2.80	Nil
Hassan Abdal	2004-05	3.0	1.5	0.67	0.02	Nil	Nil
	2005-06	3.5	1.0	0.67	0.11	Nil	Nil
	2006-07	3.5	2.0	0.67	0.45	Nil	Nil
	2007-08	9.40	2.60	1.34	0.46	Nil	Nil
		90.0	0.50	60.53	Nil	9.10	Nil

Table 10. Ranges of different parameters year-wise.

Year	EC (µS/cm)		TDS (mg/L)		Ca^{2+}+Mg^{2+} (me/L)	
	Max.	Min.	Max.	Min.	Max.	Min.
2004-05	6560	425	4592	297.5	42.0	Nil
2005-06	10590	352	7413	246.4	90.0	2.6
2006-07	9160	352	6412	246.4	50.0	3.30
2007-08	6100	399	4270	279.3	50.0	0.40
	10590	352	7413	246.4	90.0	Nil
	Na^+ (me/L)		CO_3^- (me/L)		HCO_3^- (me/L)	
	Max.	Min.	Max.	Min.	Max.	Min.
2004-05	33.42	0.04	0.50	Nil	20.0	2.0
2005-06	48.4	0.08	Nil	Nil	13.7	2.0
2006-07	81.60	0.17	Nil	Nil	8.50	2.80
2007-08	49.0	0.49	Nil	Nil	14.50	3.20
	81.60	0.04	0.50	Nil	20.0	2.0
	Cl^- (me/L)		SAR		RSC (me/L)	
	Max.	Min.	Max.	Min.	Max.	Min.
2004-05	54.0	1.0	22.0	Nil	5.5	Nil
2005-06	90.0	0.60	32.26	0.05	7.70	Nil

2006-07	75.0	0.50	36.42	0.09	1.50	Nil
2007-08	42.0	0.80	60.53	0.30	9.10	Nil
	90.0	0.50	60.53	Nil	9.10	Nil

Water samples in arid regions are high in Ca+Mg but water samples high in SAR are associated with low Ca+Mg relative to Na concentration. In soils having pH above 9.0, Ca+Mg in soil extracts seldom exceed 2 meq/L. The soluble Ca + Mg are usually low in solution having appreciable concentration of CO_3+HCO_3 (7). The absence of CO_3 and HCO_3 is not known to have detrimental effect on plant growth. However, these ions have toxic effects when occur in soil solution in appreciable concentration. Bicarbonates (HCO_3) associated with Na cause Fe chlorosis in plants, reduce elongation in radish seedlings apart from depressing protein synthesis, marked decline in vigour of apples. Carbonates (CO_3) even in small amounts result in deficiency of Ca+Mg, render soil water caustic and corrosive preventing development of good tilth. Higher concentration of CO_3+HCO_3 relative to Ca+Mg in irrigation water favours accumulation of exchangeable Na. Eaton (9) defined RSC as the sum of CO_3+HCO_3 minus the sum of Ca+Mg, expressed each ion in me/L and found a correlation between RSC and occurrence of sodic soils. Adding acid or acid forming fertilizer can control the concentration of CO_3 and HCO_3 in irrigation water. Wilcox *et al*. (45) observed adverse effect on soils and plants when RSC exceeds 1.25 me/L. The water of SAR < 10 can be safely used on almost all soils. The water of SAR 10-18 can be safely used on coarse textured soil with good soil permeability. The water of SAR 18-26 will cause much greater Na hazard and its use will demand regular application of sufficient water in excess of water requirement to flush out sodium salt deposited by irrigation and it is feasible under conditions of satisfactory drainage. The water of SAR >26 is unsatisfactory for irrigation and can be treated with H_2SO_4 or $CaSO_4$. $2H_2O$ for reducing SAR. Ali *et al.* (2) described that no doubt accumulation of exchangeable sodium correlated with RSC and SAR of the water but a water with RSC <1.25 or even 0 me/L may sodicate the soil. Dilution of such water or any brackish water if desired should not be the basis of RSC parameter.

RECOMMENDATIONS

Good quality water

1. Improved moisture conservation and water management practices alongwith modern technologies should be adopted to save and utilize precious good quality water resources like deep ploughing in monsoon,

lining of water courses, drip and sprinkler irrigation for high value crops, vegetables and fruit plants.

2. Fallowing and leaving the soil barren should be avoided. Stubbles should remain on soil surface as mulch and protective vegetative cover to control water erosion on the sloppy lands. Mulches not only conserve moisture but also control weeds.
3. Deep rooted pulses and oilseed crops should be preferred for moisture exploration from deeper soil profiles.
4. Application of farm yard manure, poultry manure and gypsum in soil is advised which not only conserves moisture but also provides nutrition to crops.

Saline water

1. Salinity has negative impact on the crop productivity due to ion imbalance and osmotic effects; therefore, salt tolerant species/varieties of crops, fruits and vegetables should be grown on the soils irrigated with high EC water.
2. Additional 15-20 percent water per irrigation is recommended in addition to normal irrigation as a leaching requirement of salts from the upper soil depths and root zone.
3. With change in water table depth, good quality water is available at about ≥70 m depth. So lowering in bore depth is advised for exploration of good quality water.

Saline-sodic and sodic water

1. Gypsum blocks should be placed near source in the water tank or channel. In the soil to be irrigated, 20-40 bags of powdered gypsum per year on the basis of gypsum requirement should be mixed in soil to avoid deleterious effects of water on soil properties and crops.
2. Organic manures like farm yard and poultry manures are advised for application for lowering soil pH to dissolve/activate native calcium.
3. Green manuring with guar, sesbania. alfalfa, etc. should be practiced in monsoon season and rottening be completed before sowing of rabi crops.
4. Salt tolerant species of crops, fruits and vegetables to EC and SAR are advised on the soils irrigated with saline sodic water.

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Annexure I

Salient features of small dams in district Attock

Name of dam	Height of dam (feet)	Gross storage capacity (acre feet)	Canal command area (acres)	Year of completion	Capacity of irrigation channel (cubic feet)	Length of channel (feet)
Sipiala	37.58	565	140	1964	2.00	15840
Ratti Kassi	50.15	2116	650	1970	4.50	23232
Kanjoor	63.25	2627	2000	1978	11.00	25344
Chhanni Bor	660.00	1958	1500	1979	6.00	19536
Qibla Bandi	72.00	3650	850	1971	6.00	15523
Shahpur	85.00	14320	1250	1986	15.00	39442
Mirwal	60.00	3765	1050	1990	11.00	16949
Jabbi	71.50	3079	1495	1991	15.57	24182
Shakardara	115.00	5711	4200	1994	46.22	122866
Basal	65.00	1700	500	2004	4.25	11500
Thatti Saydan	42.65	600	300	2005-06	3.75	10000
Sawal	99.00	2400	930	2005-06	9.50	37000
Talikna	57.87	2050	1000	2005-06	7.00	15000
Jabba	83.60	860	400	2005-06	3.75	7800
Jalwal	60.00	5000	2364	2005-06	23.00	12500
Haji Shah	66.25	2200	1520	Under construction	13.75	
Total			20149			

Source: Small Dams Organization, Rawalpindi, Brief 2007.

Annexure II

Rainfall (mm) in district Attock from 2004 to 2008

	Attock					Fateh Jang				
Month	**2004**	**2005**	**2006**	**2007**	**2008**	**2004**	**2005**	**2006**	**2007**	**2008**
January	**87**	**45**	**60**	**0**	**43**	**101**	**45**	**38**	**0**	**54**
February	**21**	**160**	**5**	**200**	**28**	**56**	**150**	**07**	**175**	**33**
March	**0**	**113**	**29**	**145**	**0**	**0**	**115**	**53**	**62**	**1.5**

April	75	40	13	26	145	102	12	20	0	93
May	25	25	15	39	10	11	16	39	13	48
June	44	1	25	101	69	117	37	82	119	181
July	106	226	152	88	101	142	251	181	163	126
August	111	198	128	121	101	62	123	208	169	235
September	23	130	35	54	56	9.5	43	34	103	60
October	65	14	13	0	6	82	65	15	00	0
November	16	4	9	27	5	22	0	21	33	45
December	85	0	47	0	45	57	0	47	00	48
Total	658	956	531	801	609	762	857	745	837	925
Average			711					825		

Annexure II contd…

Month	Pindi Gheb					Jand.				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
January	50	29	07	0	16	0	91	40	0	12
February	19	81	27	94	09	0	122	0	183	0
March	0	77	12	70	0	0	116	33	47	05
April	35	4	8	5	32	0	0	08	00	130
May	11	29	8	8	0	0	44	0	00	0
June	37	27	42	50	35	0	10	61	192	35
July	54	141	55	47	48	75	130	119	129	33
August	32	61	84	80	107	107	60	78	91	163
September	19	23	73	5	0	168	28	25	99	17
October	14	0	0	0	0	43	40	0	0	0
November	12	0	7	12	4	21	0	8	25	12
December	56	0	21	0	24	51	0	37	00	32
Total	339	472	344	371	275	465	641	409	766	439
Average			360					544		

	Hassan Abdal				
Month	2004	2005	2006	2007	2008
January	0	99	68	0	74
February	0	253	16	115	38
March	0	113	26	122	2
April	0	0	20	4	108
May	6	8	47	18	7
June	152	44	63	77	226
July	259	359	194	184	241
August	288	221	457	73	207
September	124	16	87	47	105
October	113	48	23	0	14
November	40	6	31	26	23
December	106	29	52	00	69
Total	1087	1196	1084	666	1114
Average			1029		